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UNIVERSITY OF ALBERTA

THE ALPINE VASCULAR FLORA AND VEGETATION OF PROSPECT MOUNTAIN, FRONT RANGE, ROCKY MOUNTAINS, ALBERTA

by

Ⓒ PATRICIA R. MORTIMER

A THESIS
SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
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FALL 1978

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "The alpine vascular flora and vegetation of Prospect Mountain, Front Range, Rocky Mountains, Alberta" submitted by Patricia Rosemary Mortimer in partial fulfilment of the requirements for the degree of Master of Science.

George H. La Roi
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Date August 8 1978

ABSTRACT

The alpine vascular flora and vegetation of Prospect Mountain, a suspected glacial refugium in the Front Ranges of the Alberta Rocky Mountains, were described quantitatively and qualitatively. Previous studies of the alpine vegetation on two heavily glaciated mountains in the Maligne Range at the same latitude, Signal and Bald Hills, were used for comparison. Soils, climate and glacial history of these two main study areas were also compared to determine their relative roles in accounting for the observed differences in flora and vegetation.

The vascular flora of Prospect Mountain consists of 191 species in 34 families. These species were divided into 9 main geographic distribution types. Twenty-one of the species have disjunct populations on Prospect.

The vegetation was classified into 16 community types within 5 tundra groups, using similarity matrices, cluster analysis and field observations. The Rock Tundra Group, dominated by *Dryas integrifolia*, covers the steep slopes and has the greatest areal extent. Shrub Tundra is found on the lower alpine slopes directly above treeline. Heath and Snowbed Tundra are restricted to small snow accumulation hollows. Meadow Tundra is common on the gentle slopes and flat areas. The distribution of community types and tundra groups along altitudinal and snowmelt gradients was studied using transects.

The alpine soils of Prospect have developed on limestone colluvium and are high in pH, calcareous and dark coloured. Regosols dominate.

Prospect and Signal have a vascular floristic similarity of 56%.

For Prospect and Bald Hills it is 58% and for Signal and Bald Hills it is 81%. In comparison with the Maligne Range study areas, the Prospect flora contains more Leguminosae and Salicaceae species, and fewer Ericaceae species. The Prospect flora is also composed of more North American low-elevation and arctic-alpine species, and fewer Amphi-Beringian species. There are more disjunct species on Prospect, but they are usually neither abundant nor important ecologically and they do not replace another species found in the same community in a heavily glaciated area.

Cluster analysis of the stands from all three study areas showed that most Prospect Rock Tundra, Shrub Tundra and Meadow Tundra stands are structurally and compositionally distinct from the Maligne Range stands. The Heath and Snowbed Tundra stands showed greater similarity. Ecologically equivalent communities to those on Prospect were designated for the Maligne Range where possible. A literature search revealed that the dominant *Dryas integrifolia* Rock Tundra communities on Prospect are very similar to communities in Montana and in the North American arctic.

The only significant difference measured between the soils of Prospect and the Maligne Range is pH; the Prospect soils have a higher pH. Higher summer precipitation was observed for Prospect but steep topography, coarse parent material and high winds combine to provide a xeric environment for the alpine plants. Indirect and direct ordinations showed that, of those environmental factors plotted, soil pH and moisture have the greatest correlation with stand differentiation. Snow depth and release date may also be significant but they could not be plotted.

Edaphic differences between Prospect and the Maligne Range have the greatest differentiating effect on the vascular flora and vegetation through the differing edaphic optima of numerous species, especially dominant species. The differences in dominant species so caused effect differences in community types and vegetation patterns. Higher summer precipitation on Prospect has no noticeable differentiating effect on the flora and vegetation. Higher winter wind speeds may remove and redistribute snow and reduce the number and extent of Snowbed and Heath Tundra communities and their associated species. Glacial history seems to have had the smallest effect on the vegetation and flora of the three factors. It accounts for the presence of certain disjunct, refugial species which enrich and differentiate the Prospect flora slightly.

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INTRODUCTION

Until recently the alpine flora and vegetation of the Alberta Rocky Mountains have been poorly known. The lists of Breitung (1957), Moss (1959) and Porsild (1959) form the basis of our knowledge of the flora, to which later additions have been made (Packer and Dumais 1972, Packer 1974a). Ecological studies of the alpine vegetation are even more recent and have been carried out, from south to north, at Waterton Lakes National Park (Kuchar 1973), Plateau Mountain (Bryant 1968, Bryant and Scheinberg 1970), Highwood Pass (Trottier 1972), Ram Mountain (Johnson 1975), Snow Creek (Beder 1967), Sunshine (Knapik *et al.* 1973), Bow Pass (Broad 1973), Wilcox Pass (Crack 1977), Signal Mountain (Hrapko 1970) and Bald Hills (Kuchar 1975).

With the greater knowledge of the flora gained through such studies and more extensive collection, some unusual species distribution patterns were recognised. In particular some populations were found in the Alberta Rocky Mountains which were quite disjunct from their major distributional centers further north or south. The concentration of a number of these species in Mountain Park area of the Front Range (52° 50' N, 117° 20' W) suggested the possibility of their persistence here in a refugium during Pleistocene glaciation (Packer and Vitt 1974).

Glacial refugia within the limits of continental ice sheets are of two main types, coastal refugia (Dahl 1946) which bordered on the sea on at least one side, and nunataks which were completely surrounded by ice (Fernald 1925). Using this definition the Mountain park refugium would be of the latter type. Evidence for the existence of such refugia has, in the past, been primarily biological in nature, deduced from the present day distributions of plants and animals. Geological evidence, though sometimes in direct contradiction, has also been found to reinforce this biological evidence. In the case of the Kodiak Island refugium in Alaska, a possible refugium suggested by geological information was later confirmed with biological evidence (Karlstrom and Ball 1969).

That organisms could exist in such a rigorous environment as would be expected in a nunatak situation has often been questioned. However, in the investigation of present day nunataks in the St. Elias Mountains in the Yukon, Murray (1968) has found that the severe conditions produced by the surrounding glaciers have not prevented the establishment of plants; one nunatak supports a total of 90 vascular and bryophyte species. That refugia existed and served as centers of survival during the Pleistocene has now been generally accepted by biogeographers. The considerable literature on the subject has recently been reviewed by Ives (1974).

Refugia have been proposed for a number of areas in North America, in addition to Kodiak Island including, among others, the Gulf of St. Lawrence (Fernald 1925, Morisset 1971), the Queen Charlotte Islands (Calder and Taylor 1968, Schofield 1969), southwestern Yukon (Porsild 1966, Murray 1968) and the Mountain Park area (Packer and Vitt 1974).

The evidence for a glacial refugium in the Mountain Park area has come from both biological and geological sources. Biological evidence is drawn from the distribution patterns of plants, crustaceans, beetles and butterflies. Packer and Vitt (1974) have outlined the botanical evidence provided by the presence of disjunct populations of a number of vascular and bryophyte species. Packer (1977) discussed the evidence provided by the widely disjunct populations of certain crustaceans and beetles. Disjunct populations of two species of crustaceans, *Salmasellus steganothrix* Bowman (Clifford and Bergstron 1976) and *Polyartemiella hazeni* Murdoch (Daborn 1976), have been found at Cadomin near Mountain Park. Belicek (1976), has reported the occurrence of the primarily arctic beetles *Hippodamia ulkei* Crotch and *Amara alpina* Payk here. *Amara alpina* is also known from the Plateau Mountain and Nordegg areas. G. Ball (pers. comm.) has collected the arctic beetle *Chryosolina hudsonica* Brown on Prospect Mountain near Mountain Park which represents a major disjunction from its northern populations. Pike (1978) has outlined the biogeography of North American alpine butterflies and recommends their use as indicators of refugia. He lists three butterflies from Mountain Park with interesting distribution patterns. *Bolaria improba*, which is usually restricted to the mountains of Alaska and the Yukon, has a disjunct and phenotypically distinct population on Prospect Mountain. *Bolaria eunomia nichollae*, also collected here, is rare and endemic to the Alberta Rockies. *Oeneis bore edwardsi*, which is fairly common in the southern Rocky Mountains, has two major disjunctions to the north, one in the Mountain Park area.

Geological evidence, which is discussed more fully later, has come from the study of surficial deposits in the area (Bayrock and Reimchen 1975) and the reconstruction of Laurentide and Cordilleran glacial advances (Reeves 1973, Boydell 1972, Roed 1968). The geological conclusion reached is that ice-free areas were available to serve as refugia here during both the Pre-Wisconsin and Wisconsin times.

Prospect Mountain lies well within the boundaries of the suspected Mountain Park refugium. Although plant collections have been made here, and the distinctive nature of the flora noted, no attempt has been made to quantify this. The existence of such a well documented refugial area presents the opportunity to examine more closely the present character of both the flora and vegetation of a past refugium. Many questions can be raised on this subject which warrant investigation.

1) How different are the plant communities found in refugial areas compared to glaciated areas, with respect to species composition and structure?
2) Do the refugial species (species which survived in the refugium and which are presumed mostly absent in heavily glaciated areas) play an important ecological role? Are they replaced in this role by other species in the glaciated areas?
3) Do the refugial species form their own communities or are they spread throughout the vegetation?
4) In what habitats are the refugial species found and are these related to the past nunatak environment?
5) Has the length of time available for establishment and development of plant communities affected the species richness and diversity exhibited?

In order to investigate these questions, a control site which has been heavily glaciated is required for comparison. To avoid differences in flora due to the introduction of new floral elements with a change in latitude, the comparative site should be in close proximity. A comparative approach has been used by Bird (1974b) who compared the alpine and low-elevation flora of glaciated and unglaciated areas in the Yukon and Northwest Territories. See (1978) used this method to study the alpine macrolichen flora and communities of a glaciated and unglaciated area in the Yukon.

Two ecological studies have been completed in the Maligne Range, Jasper National Park, at Signal Mountain (52° 40' N, 117° 59' W; Hrapko 1970) and Bald Hills (52° 40' N, 117° 41' W; Kuchar 1975), just 43 and 33 km away respectively. These studies of heavily glaciated alpine areas provide suitable material for comparison with Prospect Mountain. In order to evaluate the role of glacial history as a determining factor in the differences in vegetation and flora between the two areas, environmental factors which might also be factors, such as soils and climate, must also be compared. Pigott and Walters (1954) have stated that in the study of the present-day distributions of plant species "... the interpretation must contain both an 'historical' and an 'ecological' element, and any view ignoring either is at best an incomplete one."

The plant life of two areas can be examined and compared on three levels - flora, plant community and coenocline. A knowledge of the flora can be used to calculate floristic similarity between sites. However, not all plants are equally abundant or ecologically important, therefore which species combine and in what relative amounts, to form the characteristic plant communities for an area is also important. Major differences in flora do not necessarily imply major differences in plant communities. The plant communities form recurrent sequences or coenoclines on the landscape, in relation to environmental gradients, which can also be compared. Comparison at any one level can yield valuable information, but comparison at all three is necessary for a complete and comprehensive understanding of the existing differences.

The general objectives of this study are to characterize the alpine vascular flora and vegetation of the suspected refugial area, Prospect Mountain, and to compare these features with their analogues in the heavily glaciated Signal Mountain and Bald Hills. More specifically the objectives are:

1) to describe qualitatively and quantitatively the alpine vascular flora and vegetation, soils and climate of Prospect Mountain;
2) to classify the vegetation into its component community types;
3) to determine the role of refugial species in the vegetation;
4) to compare qualitatively and quantitatively the vascular flora, soils and climate of Prospect Mountain, Signal Mountain and Bald Hills;
5) to compare qualitatively and quantitatively the vegetation units (stands and community types) of the three areas;
6) to compare the arrangement of plant communities in coenoclines in the three areas using transects;
7) to determine the relative effects of differences in soils, climate and glacial history on the alpine vegetation and flora on Prospect Mountain.

STUDY AREA

Location

Prospect Mountain is at the eastern edge of the Front Ranges of the Rocky Mountains in Alberta (52° 55' N, 117° 22' W), 86 km SSW of Edson along Hwy. 47 and 8 km S of Cadomin along the Grave Flats Road (Fig. 1). Good access to the alpine zone is gained through an abandoned mining road along Prospect Creek which terminates at an elevation of 2040 m ASL. Although easily accessible during the summer the area is virtually inaccessible for the other eight months of the year.

The study was carried out on the eastern slopes of Prospect Mountain in the alpine zone, defined as the zone above the growth of stunted trees or krummholz with supranival leaders (Hrapko 1970).

Physiography and Geology

Prospect Mountain rises to a peak of 2757 m with a second peak of 2684 m to the SE. It is joined to the adjacent, flat-topped Cheviot Mountain with a shallow col between them. Bare cliffs and steep scree slopes characterize the top 500 m. Spreading out to the NE from the rock face are four, near-parallel ridges, labelled R1 to R4, west to east for reference (Fig. 2). The two outside ridges have concave tops and are separated from the inner ridges by two large cirques connected to deep V-shaped valleys. The central ridges are convex and separated by a narrow steep-sided valley.

Meltwater streams from the snowy peak run in all three valleys with the heaviest flow in the deeper outer valleys. The streams join

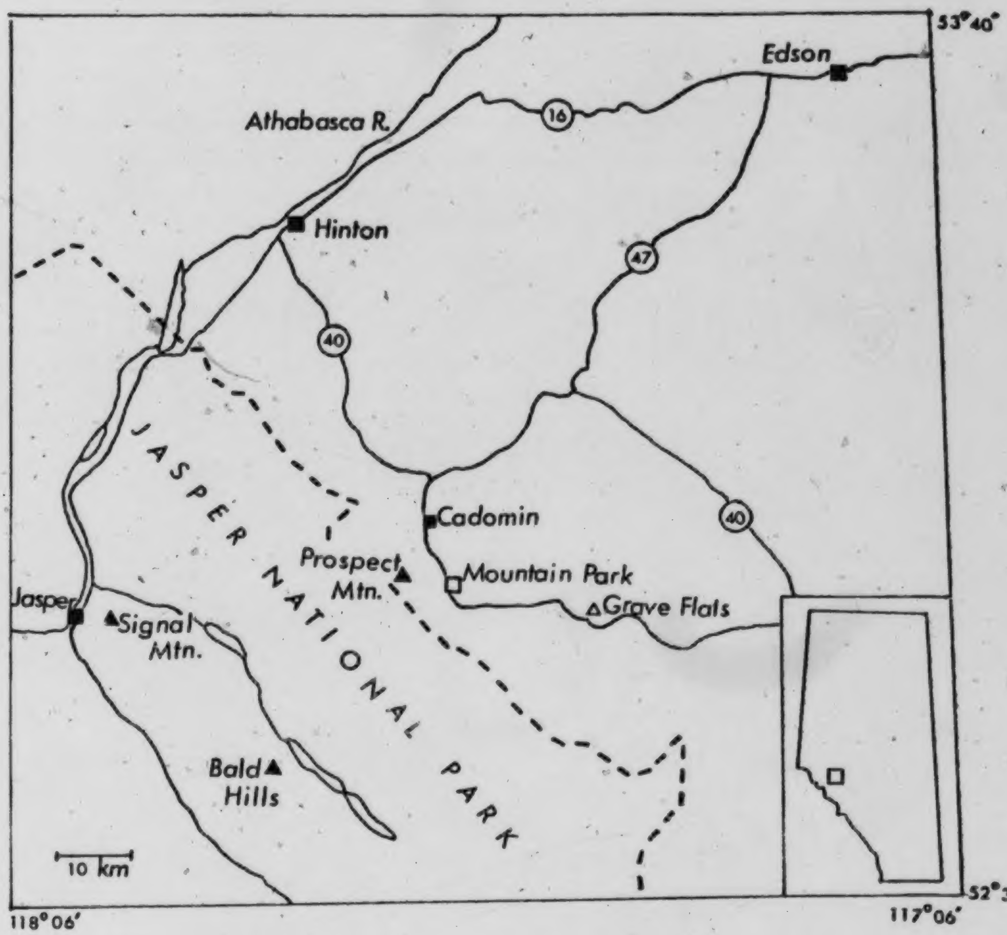

53°40′
Edson
16
Athabasca R.
Hinton
47
40
JASPER NATIONAL PARK
Cadomin
40
Prospect Mtn.
Mountain Park
Grave Flats
Jasper
Signal Mtn.
Bald Hills
10 km
52°30′
118°06′
117°06′

Fig. 1. Location of Prospect Mountain, Alberta.

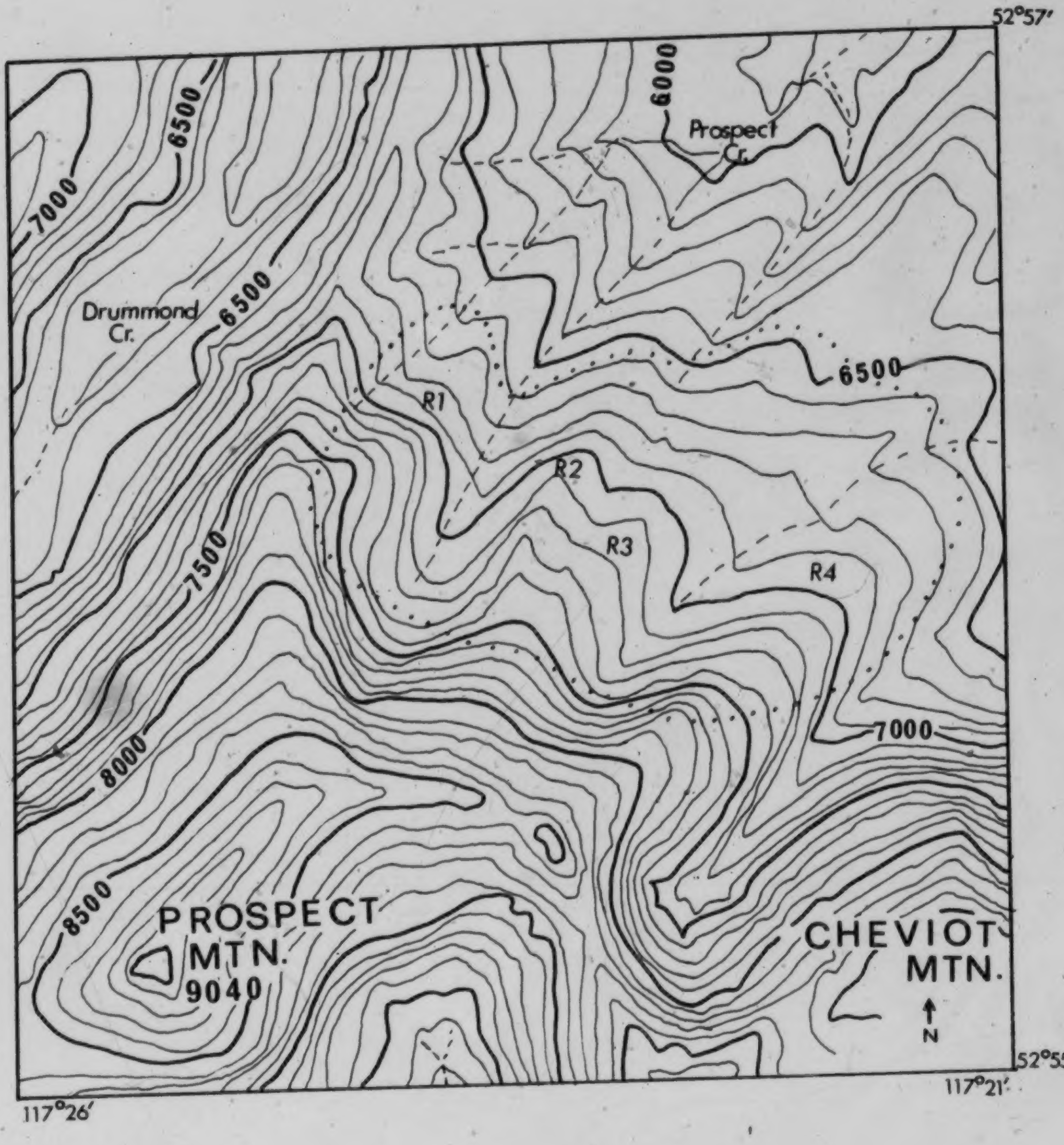

52°57′
6000
Prospect Cr.
6500
7000
Drummond Cr.
6500
6500
R1
R2
R3
R4
7500
8000
7000
8500
PROSPECT MTN. 9040
CHEVIOT MTN.
N
52°55′
117°21′
117°26′

Fig. 2. Topographic map of Prospect Mountain. Contour interval is 100 feet. The study area is that within the dotted line.

at the base of the mountain to form Prospect Creek, which in turn empties into the McLeod River to the east.

The SW side of the mountain has precipitous cliffs and scree slopes falling sharply to the Cardinal River Valley below. Because of this the study was restricted to the more gentle eastern slopes (Fig. 2).

Prospect Mountain is on the Nikinassin Thrust Sheet at the edge of the Front Ranges (Kilby 1978). The McConnell Fault, which has been used to divide the Front Ranges from the Foothills to the east (Mountjoy 1962), traverses Prospect Mountain above and to the west of the study area. However, Stott (1963) defines the boundary of the foothills as the eastern base of the Front Ranges, indicated by the presence of Paleozoic sedimentary rock. The situation in this area is complicated by the presence of the Nikinassin Outlier, capped by Paleozoic shale and limestone, to the east of Prospect Mountain. Therefore, for the purposes of this study, Prospect Mountain is considered to be in the Front Ranges, a position supported by earlier workers (Packer and Vitt 1974, See 1978).

The bedrock geology of the area has been mapped by MacKay (1929) and described by later workers including Irish (1963), Mellon (1966) and Holter and Mellon (1972).

The McConnell Fault separates the Paleozoic formations from the Lower Cretaceous Nikinassin formation beneath. These Paleozoic formations belong to the Fairholme group and are Devonian argillaceous limestone, calcareous shales and dolomite. Higher peaks in the area are topped by the massive Palliser formation but this appears to be absent on Prospect.

Plate 1. A view of Prospect Mountain from the east showing the main ridges covered with alpine tundra vegetation leading to the bare rock face and twin peaks. An abandoned mining road is visible to the right of the picture. The slow forest regeneration after the 1913 fire can be seen in the foreground.

The Nikinassin formation is composed of hard grey sandstone and dark grey shale with quartz cement as opposed to the clay cement of the lower Luscar beds, and is therefore more erosion resistant (Mellon 1966).

Most of the lower slopes are underlain by the Lower Cretaceous Luscar formation, separated from the older beds above it by a fault. The Luscar formation consists of grey sandstone and dark grey shale with commercial-grade coal beds in some areas.

The lower slopes of R4 are also composed of the Lower Cretaceous Mountain Park formation. This formation consists of coarse-grained, green sandstone and greenish-grey shales with scattered lenses of chert pebble conglomerate, and is difficult to distinguish from the Luscar formation. Within the Mountain Park formation there is a small outcrop of Blackstone formation, an Upper Cretaceous formation of dark marine shales.

Both the Mountain Park and the Luscar formations are obscured in the study area by a thick layer of colluvium derived from the Paleozoic rocks which form the peak of the mountain. The bedrock is visible only in outcrops and it is the colluvium which forms the main soil parent material.

Periglacial Features

Periglacial features, produced by frost action, mass wasting, wind, and nivation, are particularly important on Prospect Mountain. Patterned ground is more extensive here than is continuous vegetation. There are two main terminologies for periglacial features, based either on formative process (Washburn 1973) or description (Nicholson

1976) However, as these workers have based their classification systems on predominantly arctic examples, many alpine features do not easily conform to either system. Therefore the terms used to describe the periglacial features on Prospect are drawn from a variety of sources.

Woods (1977) has studied the sensitive relationship between slope and patterned ground on Plateau Mountain in the southern Alberta Rocky Mountains. He reports a trend, with increasing slope, from sorted nets and circles ($\bar{x}$ slope = 1°) to flow features ($\bar{x} = 7^{\circ}$) to stripes ($\bar{x} = 12^{\circ}$) to scree slopes ($\bar{x} = 26^{\circ}$). This general trend is also evident on Prospect.

On the steepest unstable scree slopes ($\bar{x} = 33^{\circ}$) plant cover is reduced to mats or islands of *Dryas integrifolia*, the "spotted tundra" of Bamberg and Major (1968). On steep, but less precipitous slopes ($\bar{x} = 24^{\circ}$), "contiguous vegetation stripes" (Nicholson 1976), perpendicular to slope contours are common. The stripes are marked by alternate bands with and without vegetation. The vegetated portions are dominated by *Dryas integrifolia* in association with various subdominants. Relief is less important than vegetation in marking the stripes, which may be level or slightly banked. When banked they resemble the "miniature *Dryas*-banked terraces" of Benedict (1970), formed through the interaction of wind, frost creep and vegetation.

On gentler slopes ($\bar{x} = 12^{\circ}$), below the vegetation stripes, are small solifluction or "turf-banked terraces" (Benedict 1970). At the transition between the terraces and stripes, the stripes increase in relief to resemble "nonsorted steps" (Washburn 1973), which grade into the turf-banked terraces. The latter, 0.2 - 1 m high, are oriented

Plate 2. The S-facing slope of R3 showing the extensive vegetation stripes on the steeper slopes. Gentler slopes on the ridge are covered with continuous *Dryas* meadow communities. Dark green areas are krummholz surrounded heath hollows. The snow covered areas also contain heath communities. (June 24, 1976)

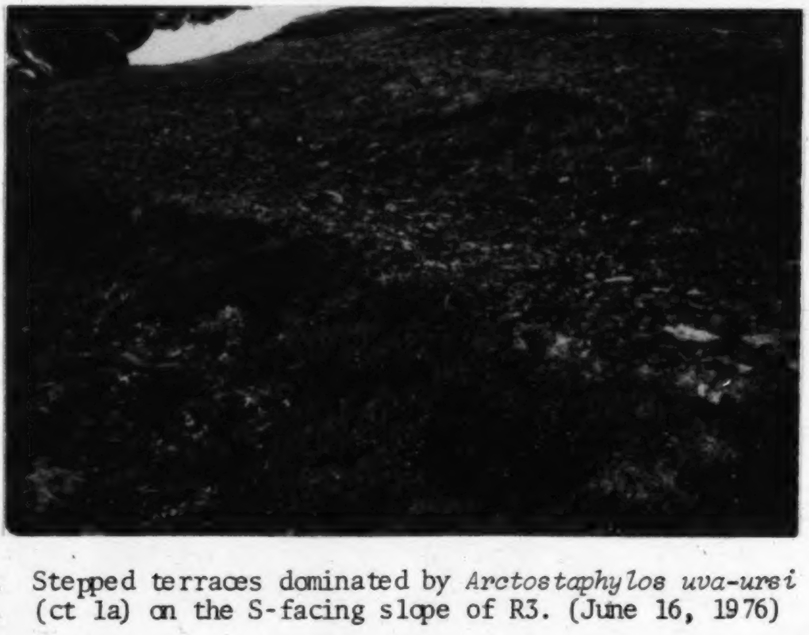


Plate 3. Stepped terraces dominated by *Arctostaphylos uva-ursi* (ct 1a) on the S-facing slope of R3. (June 16, 1976)

obliquely at the transition point but become parallel to slope contours further downslope. Plant cover is higher on the terrace risers than on the rocky treads and is often shrubby in nature.

An alternative to these small solifluction terraces occurs in localized areas on the south face of R3. On this dry slope, long, very regular, parallel, rocky steps or terraces are situated perpendicular to slope contours on the gentler slopes below the vegetation stripes. The risers, 0.5 - 1 m high, are covered with *Dryas integrifolia* and *Arctostaphylos uva-ursi* and rise sharply to the barren rocky treads (Plate 3). These features most closely resemble the "*Dryas* stepped terraces" of Bamberg and Major (1968).

Larger solifluction lobes, 1 - 2 m high, are found in only one location on the mountain. Unlike the smaller solifluction terrace risers which support a number of community types, the larger lobe risers are covered with a single community type.

"Nonsorted circles" (Washburn 1973) or "contiguous vegetation equiforms" (Nicholson 1976) are encountered occasionally in areas with a slope of 0 - 5°, but they do not cover significant areas. Level sites are more commonly covered with continuous vegetation or rock tundra without patterning.

Glacial History

Studies of the surficial geology and glacial deposits in Alberta and parts of Saskatchewan indicate that there was no Laurentide glaciation in central and NW Alberta prior to the Wisconsin period (Williams and Bayrock 1966, Bayrock 1969). Pre-Wisconsin Cordilleran glaciers did cover the foothills as evidenced by the presence of glacial erratics at elevations above 2440 m throughout the area (Bayrock and Reimchen 1975). In general, during all glaciations before Wisconsin times, an ice-free land corridor extended from Montana to the Arctic along the East Slope of the Rocky Mountains (Bayrock 1969).

During the Wisconsin, Cordilleran glaciers flowed eastward along the main river valleys into the foothills. Rutter (1966, 1972) has given evidence for a series of advances in the Bow Valley which flowed beyond the Front Ranges, however there is no evidence of coalescence with the continental glaciers. Further north, in the Rocky Mountain House region, Laurentide ice sheets covered the area to an elevation of 1660 m for most of the Wisconsin (Boydell 1972). Higher mountain ranges in the area, such as the Brazeau and Ram, would therefore be nunataks exposed above the ice surface.

The best documented coalescence of the Cordilleran and Laurentide ice sheets occurred in the Athabasca River Valley in the early Wisconsin or late Illinoian times (Roed 1968, 1975). Ice from the Cordilleran glaciers flowed across the foothills, made contact with the Laurentide sheet in a zone 8 - 30 km wide, and then flowed SE along the eastern front of the foothills. Areas along the mountain and foothills junction adjacent to the Athabasca coalescence were either ice-free, covered with proglacial lakes, or covered with Cordilleran piedmont lobes (Reeves 1973). Bayrock and Reimchen (1975) have mapped the surficial geology of the Mountain Park area and define the areas unglaciated in this period by the presence of old tills and associated colluvial deposits on steep slopes. Such colluvial material is present over most of the slopes of Prospect Mountain.

Since the coalescence of the two ice sheets in the early Wisconsin, the western edge of the Alberta plains has been free of ice, with the late Wisconsin ice front to the NE of the foothills and Front Ranges (Reeves 1973). Local alpine glaciers moved down the valleys of the Front Ranges but did not extend into the main valleys. Southern Alberta was ice-free by 15,000 BP and the mountain valleys by 10,500 BP (Reeves 1973).

Bayrock (1969) concludes that the continuous ice-free corridor, along the mountains from Montana to Alaska, was open during the Kansan, Nebraskan and Illinoian times of the early Pleistocene. During the Wisconsin this clear passage was closed in a few known locations for indeterminant intervals.

Soils

Soils of the forested areas adjacent to Prospect are mainly Orthic Grey Luvisols in association with Orthic Dystric and Eutric Brunisols (Dumanski *et al.* 1972). Although the forest soils on the slopes of Prospect itself have not been surveyed, they are probably very similar.

Alpine soils of the study area have not been previously examined. Although the study area falls within the Regosolic soil area delineated by Clayton *et al.* (1977), a number of other soil orders are also found here.

Alpine soils have recently been described for a number of sites in the Canadian Rocky Mountains including Waterton Lakes National Park (Coen and Holland 1976); Snow Creek Valley (Baptie 1968) and Sunshine (Knapik *et al.* 1973), both in Banff National Park; Signal Mountain (Hrapko 1970), Bald Hills (Kuchar 1975) and Marmot Creek Basin (Beke and Pawluk 1971) in Jasper National Park; and Yoho National Park (Coen 1978). Biophysical studies are now in progress in Banff and Jasper National Parks encompassing alpine regions (Wells *et al.* 1976, 1977); the eastern Ranges within the Parks, including areas directly west of Prospect, are to be surveyed in 1978 (G. Coen pers. comm.).

Climate

Prospect Mountain is located in the Subarctic or Cold Snowy region (Dfc) of the Köppen classification system (Strahler 1951).

Powell and MacIver (1976) have summarized the meteorological data available for the surrounding area for a 10-year period, however only general trends can be derived from this. For the Mountain Park area the May to September mean temperature is shown to be about 6 °C, total number of days with a mean temperature greater than -2.2 °C is about 125 and the total precipitation is about 450 mm. Root (1976) collected and presented meteorological data for the summer of 1972 in the vicinity of Cadomin, only 8 km from the study area, at an elevation of 1675 m ASL.

The closest reporting station is the Grave Flats Lookout, 25 km SE of Prospect, maintained by the Alberta Forest Service from May to September. At an elevation of 2074 m ASL it is situated well above treeline. Although built in 1924 (Ross 1974), continuous meteorological records are not available since then. Thirty-year (1941 - 1970) calculated normals for the Grave Flats Lookout are presented in Table 1, and the data for 1976 in Table 2.

Table 1. Thirty-year normals for summer precipitation and mean temperature at Grave Flats Lookout, 1941-70 (Environment Canada 1975).

	Precip. (mm)	$\bar{x}$ Daily Temp. (°C)
June	100	6.7
July	111	10.1
August	90	9.4

Table 2. 1976 meteorological data for Grave Flats Lookout (Alberta Forest Service unpublished data).

	Temperature (°C)				Precipitation		$\bar{x}$ Wind
	$\bar{x}$ Max.	$\bar{x}$ Min.	Max.	Min.	Rain mm	Snow mm	km/h
June	9	1	19	-4	45.1	16.7	16 W*
July	14	5	21	0	77.7	0	13 SW/W
Aug.	13	6	18	0	135.0	0	15 W

* prevailing direction

Vegetation and Flora

The Rocky Mountains stretch from 60 °N to 32 °N and their associated vegetation varies over this latitudinal length. Daubenmire (1943) divided the Rocky Mountains into 4 latitudinal floristic divisions. Ogilvie (1962) later divided the Alberta Rocky Mountains into North and South areas at the 50 °N latitude based on floristic differences. Prospect Mountain is located near the boundary between Daubenmire's Northern and Far Northern divisions and in the Northern area of Ogilvie.

Forests of the lower slopes and valleys below the study area are of the Subalpine Forest Region, more specifically the East Slope Rocky Mountain Section (SA.1) of Rowe (1972). A number of elements make up the forest flora but wide-ranging boreal and cordilleran species account for most of it. There is an increase in boreal forest elements over cordilleran elements with an increase in latitude in the Canadian Rocky Mountains (Ogilvie 1960). The dominant tree species in the subalpine region, *Picea engelmannii*, *Abies lasiocarpa* and *Pinus contorta*, show very close relationships to and hybridize with their counterparts, *Picea glauca*, *Abies balsamea* and *Pinus banksiana*, of the boreal forest (Rowe 1972).

The valleys and low hills surrounding Prospect are covered with an open forest of *Pinus contorta*, the result of an extensive fire in 1913 (Ross 1974). On the lower slopes and in the subalpine zone of Prospect, *Picea engelmannii* and *Abies lasiocarpa* dominate. Both species continue into the alpine as krummholz with *A. lasiocarpa* attaining the highest altitudes. Treeline ranges from about 1980 m on N-facing slopes to 2100 m on S-facing slopes. At and below treeline, lush subalpine heath communities are rare.

Above treeline there is an extensive alpine zone with a flora composed of floristic elements quite different from those of the forests below. For alpine floras in general Packer (1974b) recognises the autochthonous element, evolved from the local low-elevation flora, and the allochthonous element which has come from other alpine areas. The number of autochthonous species depends on the type of low-elevation vegetation in the area, and in the heavily forested Rocky Mountains of Canada this element is negligible. In the northerly alpine floras the circumpolar arctic-alpine element is largest. Although the alpine endemic element decreases northward (Major and Bamberg 1968), endemic taxa do exist in the northern Rocky Mountains. Assuming the existence of a widespread late Tertiary arctic-alpine flora which has been decimated and modified by Pleistocene events (Weber 1965, Johnson and Packer 1967), it follows that these endemics are Tertiary relics associated with refugial areas (Packer 1971). This is also the explanation for disjunct elements, some of which exhibit close relationships to species in central Asia. The alpine flora of Prospect, as for other northern mountains, is a mixture of these various elements.

The vegetation of the lower slopes and valley bottoms above treeline is dominated by shrubs, particularly *Salix barrattiana, Salix arctica* and *Betula glandulosa.* Many of the showy subalpine herbs invade the alpine here.

Upper alpine slops are dry, and periglacial features are common. *Dryas integrifolia* dominates these slopes and *Polygonum viviparum, Salix nivalis* and *Androsace chamaejasme* are ubiquists. Legumes are also widespread. Vascular plants continue up the scree slopes almost to the peak at 2757 m ASL.

Extensive vascular plant collections have been made in the area, but no presence lists have been published for the natural plant communities. Russell (pers. comm.) has enumerated the vascular plant species growing on coal spoils in the surrounding area. The alpine macrolichens of Prospect Mountain have been studied and recorded by See (1978).

Human Impact

Although mining operations were begun in the Mountain Park area in 1911 there was no immediate effect on Prospect Mountain. In 1913 a fire started at a lumbering camp associated with the mine raged out of control for 2 days, and was eventually put out by rain (Ross 1974). The fire destroyed forests on the lower slopes of Prospect and the surrounding area and there has been little regeneration in the 45 years since then (Plate 1).

Until the 1930's there were no roads in the area; railroad and horse trail provided the only access. In 1934 roads were completed between the nearby mining towns of Cadomin and Mountain Park (Ross 1974). It is probable that the trail up the Prospect Creek was opened for coal exploration at this time. However, connections by road between Cadomin and the Jasper - Edmonton Highway did not occur until the 1940's.

Coal mining itself has made the greatest impact on the landscape on Prospect Mountain. Although the records are not complete, it does appear that two companies held leases on Prospect: Mount Cheviot Coal Co. Ltd. (1931-38), and King Coal Ltd. (1942-46) (Campbell 1967).

Exploratory strip mining was carried out in the alpine but no commercial coal was produced. The last operator in the area, King Coal Ltd., abandoned the mine at the end of World War II with the drop in demand for coal. Lake (1967) suggests that in this area "improper abandonment of the mining operations has tended to occur in the case of small companies which were undercapitalized at the beginning and bankrupt at the end." This may certainly be the case on Prospect, where remnants of buildings and machinery are scattered in the subalpine forest. Coal spoils cover large areas of one alpine ridge, and wide trenches cut through the alpine tundra are found to an altitude of 2070 m. Revegetation at these sites has been very slow. Revegetation of coal spoils in the surrounding area has been studied by Russell (pers. comm.), including high-elevation sites.

In recent years the greatest disturbance has resulted from trail bikes and four-wheel drive vehicles, entering the alpine from the old mining roads. Track marks from such vehicles are found in most communities on the mountain. Due to its low stature, alpine vegetation is more susceptible to such disturbance than the wooded vegetation of lower elevations. It is also more sensitive because of the uni-layer nature of the vegetation, the bonding qualities of the organic-mineral surface horizons, and the harsh climate which retards the natural restoring process (Wells *et al.* 1977).

Prospect Mountain lies on Reserved Crown Land which has been proposed as a permanent Ecological Reserve. This is particularly important at this time, as the use and subsequent disturbance increases annually.

METHODS

Flora

Voucher collections of all vascular taxa encountered in the study area were made throughout the 1976 field season and deposited in the University of Alberta Herbarium (ALTA). Nomenclature follows Moss (1959), Packer (1974a) and Hultén (1968), with the exception of *Minuartia austromontana*, and the genus *Draba* which follow Wolf (1977), and Mulligan (1976) respectively.

As previous botanical studies had been carried out in the area, a number of species with disjunct distributions were known to be present (Packer and Vitt 1974). When these species were encountered special note was made of their particular habitat, local distribution and abundance.

Each member of the flora was assigned to a geographic distribution type using the maps of Hultén (1968), Porsild (1973) and Packer (unpubl.) with additional distributional information gathered from Mackenzie (1940), Szczawinski (1962), Packer and Dumais (1972), Hitchcock and Cronquist (1973), Taylor (1973, 1974a, 1974b), Brayshaw (1976) and Mulligan (1976). Similar assignments were made for the species found on Signal Mountain (Hrapko 1970) and Bald Hills (Kuchar 1975).

For comparative purposes the percentage of the flora in each vascular plant family and each distribution type was calculated for the three areas. The floristic similarity between the three areas was calculated using Sørensen's coefficient of community as the similarity index: $CC(\mathrm{A,B}) = 200c/(a + b)$, where c is the number of species in common and a and b are the number of species in areas A and B respectively.

Vegetation

Community Sampling

The vegetation was sampled quantitatively using small quadrats placed randomly within uniform stands, providing data suitable for both the classification and ordination of communities (Mueller-Dombois and Ellenberg 1974). As the data collected here were to be compared to those from two previous alpine studies (Hrapko 1970, Kuchar 1975), the sampling scheme was as similar as possible to that of these workers.

After a period of reconnaissance and familiarization with the flora and vegetation, tentative community types were delineated. These community types, representing recurring plant assemblages, were required to cover a large enough area to be significant, either at a single site or at a series of smaller sites. Transitions between communities were recognized on the landscape and avoided when sampling. Representative stands were chosen for sampling which satisfied the following criteria:

1) relatively homogeneous species composition;
2) uniform physical environment;
3) no patches of another community >1 m^2 within stand;
4) minimal human disturbance - vehicular tracks did not cause rejection of a stand unless these covered a significant area or were causing obvious vegetational changes.

Sometimes more than one stand was sampled per community type. This was either intentional, where stands were small because of community size, or unintentional, resulting from the sampling of seemingly distinct areas which later proved similar on closer scrutiny.

Stands were normally 10 X 20 m (0.02 ha) and centrally located in the community, with the longer axis paralleling the slope contours. This size was large enough to include most species in the community, but small enough, in most cases, to fit within the community boundaries. This stand size has been used successfully by Kuchar (1975). Where communities had smaller dimensions than this, the stand size and the number of quadrats were halved, and where possible, a replicate stand was sampled.

Thirty quadrats 25 X 25 cm were set out in each stand. Studies by Eddleman *et al.* (1964) in the alpine have shown that quadrat size is more important than shape. The 6.25 dm^2 area of the quadrats in this study falls well within the 4 to 12 dm^2 size range considered suitable for tundra vegetation by Eddleman. This quadrat size and shape was used by Hrapko on Signal Mountain (1970), and by Kuchar on Bald Hills (1975).

Stands were sampled when it appeared that the greatest number of species was in bloom. For each stand the general topography, aspect, slope and altitude were recorded. A species list was made for the stand and the surrounding community. A random numbers table was used to place the 30 quadrats. Within each quadrat, visual cover estimates were made for the total cover of vascular plants, bryophytes, lichens and bare ground, and for each individual vascular species. The scale used was a modification of the Braun-Blanquet Cover-Abundance scale (1932). The midpoint of each class was used later in the calculation of mean cover values.

Cover Class	Range	Midpoint
6	76 - 100 %	88.0
5	51 - 75 %	63.0
4	26 - 40 %	38.0
3	16 - 25 %	20.0
2	6 - 15 %	10.0
1	1 - 5 %	2.5
+	<1 %	0.5

The lower cover classes have narrower ranges than the higher cover classes which is particularly suitable for alpine studies where most of the species have a very low cover. However, in the few cases where species do have a cover which approaches 100%, their cover values are underestimated with this scale.

Transect Studies

Two transects were sampled during the study: 1) over a series of *Dryas*-dominated stripe communities, 2) across a snow melt gradient.

The first transect ran almost N - S but cut obliquely across a series of rock stripes and terraces on a steep slope. Sixty 25x25 cm quadrats were placed over the 90 m length, 1 every 1.5 m. Cover estimates were made as described for the community sampling. Slope was measured in every quadrat and altitude every 20 quadrats.

In the second transect a 49 m line was run from a meadow in an area of late snow release, through heath communities and finally into rock stripes. Quadrats were placed adjacent to this line at 0.5 m intervals for a total of 98 quadrats. Plant cover was estimated in each quadrat as described for the community sampling. Slope was also measured in each quadrat.

Vegetation Synthesis

The sampling data were organized into species-stand tables. For each species a Prominence Value was calculated using the formula $PV = C\% \sqrt{F\%}$ where F = quadrat frequency and C = mean cover (Stringer and La Roi 1970). Using PV's a similarity matrix was constructed for the 31 stands. For comparative purposes, a similarity matrix was also constructed for all 73 Prospect, Signal and Bald Hills stands. The index of similarity (IS) used was the quantitative modification of Sørensen's coefficient of community (Sørensen 1948) as first presented by Motyka *et al.* (1950); $IS(A,B) = 200w \;/\; (a + b)$ where a is the sum of the PV's of all species in stand A, b is the sum of the PV's of all species in stand B, and w is the sum of the lesser PV's for the species common to both stands. This index is expressed as a percentage and is also referred to as Percent Similarity (PS).

Clustering Methods

Cluster methods of analysis are commonly used to form groups based on some similarity criterion. However, grouping often results in some loss of information. Ward (1963) proposed a method of cluster analysis which minimizes the loss of information associated with grouping and expresses it in a form which can be interpreted. His method, which results in minimum-variance spherical clusters, was used in this study.

A distance matrix was calculated for the stands to be clustered using the squared Euclidean distance between the stands. Sneath and

Sokal (1973) define the Euclidean distance between items j and k in an n-dimensional space as

$$d = \left(\sum_{i=1}^{n} \left(X_{ij} - X_{ik} \right)^2 \right)^{\frac{1}{2}}.$$

For each stand the n characters to be compared were the PV's of the species present. The PV's assigned to each species were coded to facilitate computer analysis using the following scale:

PV	Coded Value
0 - 1	1
1 - 10	2
10 - 30	3
30 - 60	4
60 - 120	5
120 - 240	6
240 - 480	7
480 - 960	8

Although when quantitative values are used the squared Euclidean distance (d^2) places greater emphasis on the species with high PV's, the dominants, the use of coded values may reduce or counteract this trend. Distance matrices were also calculated using binary (presence--absence) data for a possible n species in each stand.

Wishart (1969) outlined the transformation which derives Ward's method from the distance matrix. For each cluster the sum of the deviation of the points about the group mean is an indication of the group's homogeneity. The error sum of squares

$$\mathrm{ESS} = \sum_{i=1}^{n} x_i^2 - \frac{1}{n} \left(\sum_{i=1}^{n} x_i \right)^2$$

is a measure of this deviation (Ward 1963). At each step in the fusion hierarchy the union of each pair of clusters is considered and the fusion performed which results in the minimum increase in the ESS. After each fusion a new distance matrix is calculated using the new groups formed. This method is of the SAHN type of Sneath and Sokal (1973), i.e. sequential, agglomerative, hierarchic and non-overlapping.

Ward's method of cluster analysis was performed on the stands from Prospect mountain alone, using the Clustan 1C program (Wishart 1975) on the University of Alberta Amdahl 470 computer. The data collected on Signal Mountain and the Bald Hills were prepared in the same manner and clustered with the Prospect stands in other runs. Results were plotted as dendrograms using as the vertical scale a coefficient which is twice the increase in ESS caused by fusion at that level.

Indirect Ordination

To investigate the physical factors which might be significant in controlling the distribution of the vegetation, the Bray-Curtis method (Bray and Curtis 1957) of indirect ordination was employed. The method is particularly suitable where environmental gradients are unclear.

Similarity matrices were generated using PS (see above) and Sørensen's coefficient of community (CC) (Sørensen 1948). $CC(A,B) = 200c/\ (a + b)$ where a and b are the total number of species in stands A and B, respectively, and c is the number of species common to both. End-stands for the x-axis were chosen from these matrices using the criteria of (1) great dissimilarity between the two stands and (2) minimum of zero similarity values with other stands. These criteria allowed a number of end-stands to be examined in each case. The y-axis was constructed as outlined in Mueller-Dombois and Ellenberg (1974).

Stands were located in two-dimensional space according to their dissimilarity with the end-stands. CC provided the best stand separation, so this similarity index was used in the final ordinations.

All calculations were carried out on the Amdahl 470 computer using the Cornell Ecology Programs, CEP 4 (Bray - Curtis Ordination) and CEP 5 (Resemblance or Distance Matrix) (Gauch 1973).

Indirect ordinations were performed on the Prospect data alone, and on the combined Prospect, Signal and Bald Hills data.

Direct Ordination

With a high degree of floristic heterogeneity, such as is present among the three major study areas (see page 126), there is an increase in the distortion of inter-stand distances in indirect ordination (Gauch and Whittaker 1972). Where there are obvious environmental gradients, however, in this heterogeneous vegetation, direct ordination methods can be used to good advantage. For the three study areas soil pH and soil moisture gradients appeared most closely associated with vegetation patterning in the field and on the indirect ordinations. Therefore the distribution of the stands along these two edaphic gradients was examined.

Field measurements of surface soil pH were used, where possible, to place the stands along a pH gradient, the y-axis. Since some Bald Hills stands lacked pH data they were omitted from this ordination. The x-axis, the moisture gradient, was developed using the methods of Whittaker (1973) and Lee (1976). Stands were assigned a tentative moisture index from 1 to 5, from xeric to hydric. By averaging the moisture indices of the stands in which a species was present, a moisture index was computed for each species. Rare species were, of necessity, indexed subjectively. Information on the ecology of the species was also considered and the indices adjusted if necessary. The resulting indices were compared to those calculated by Lee (1976) for the same species. The final list of species moisture indices is found in Appendix III.

An unweighted (UMI) and weighted moisture index (WMI) were calculated for each stand. The UMI was calculated using the formula $UMI = \sum_{i=1}^{n} MI_i/n$ where MI_i is the MI for each species and n is the total number of species in the stand. The WMI is defined as $WMI = (\sum_{i=1}^{n} MI_i \times PV_i) / (\sum_{i=1}^{n} PV_i)$ the MI of each species, PV_i is its Prominence Value and n is the number of species in the stand.

Classification of Vegetation

The stands sampled on Prospect Mountain were organized into "community types" (ct's), i.e. recurring plant assemblages with similar composition, physiognomy and habitat, using the matrix of similarity indices (IS), cluster dendrograms, and field observations. Highly similar stands were combined to form a single ct. The ct's were given binomial names using the species with the highest PV followed by the species with the next highest PV or the greatest diagnostic value. Stands which varied distinctly but not radically in composition or structure from a particular ct were designated as "subtypes" (st's).

Community types were organized into larger Groups, and in some cases, Subgroups, by combining ct's which were similar in total plant cover, dominant species, major growth-forms, and habitat. Cluster analysis, field observations and IS values were also taken into consideration when forming the higher levels of the classification.

Thus the final hierarchy is: Group - Subgroup - Type - Subtype.

Soils

Soil Sampling

A soil pit was dug in each of the stands. The profiles were exposed until bedrock was reached or the soil became too rocky for further excavation. The horizons were recorded and their thickness measured. Notes were taken on the quantity and depth of rooting. Each profile was classified according to the Canadian System of Soil Classification (Canadian Soil Survey Committee 1978).

Bulk soil samples were taken from each horizon, dried as soon as possible, and stored in paper bags. The dried soil was screened through a 2 mm sieve, and the coarse fraction so removed was weighed and expressed as a percentage of the whole soil. Further physical and chemical analyses were done on the <2 mm fraction.

Soil Analysis

Physical analyses performed on the <2 mm fraction in the laboratory were:

1) moist colour determination, under daylight, using the Munsell colour chart (Munsell 1954);
2) pH, measured with a glass electrode pH meter, using the soil--water paste method (Richards 1954);
3) mechanical analysis, using the hydrometer method (Bouyoucos 1962, Day 1965);

4) water retention of the soil at 1/3 and 15 bar tension on ceramic plate extractors, expressed as % oven dry weight at 105 °C and recalculated on a whole soil basis (Richards 1965).

The following chemical analyses were carried out on the <2 mm fraction:

1) presence of carbonates, detected with 1N HCl;
2) exchangeable ammonium (NH_4) and nitrate (NO_3), determined by the steam distillation method (Bremner 1965);
3) exchangeable potassium, measured on an atomic absorption spectrophotometer using an ammonium acetate extraction (McKeague 1976, Chapman 1965);
4) available phosphorus, determined by the Agricultural Soil and Feed Testing Laboratory of Alberta Agriculture, using the modified Bray method where H_2SO_4 is used rather than HCl (Dickman and Bray 1940).

Meteorological Observations

A meteorological station was established on an exposed ridge at an altitude of 2088 m ASL. An aluminum, louvered instrument shelter, secured by cables, housed a Belfort recording hygrothermograph at ground level. The hygrothermograph was calibrated every two days using a Taylor sling psychrometer. A Taylor sixes type maximum - minimum thermometer was shielded and mounted outside the shelter at a height of 50 cm.

Precipitation was measured with a Taylor Clear-Vu rain guage at 60 cm and three calibrated metal cans at ground level. Values for the four gauges were averaged.

A Belfort 3-cup totalizing anemometer, situated 70 cm above ground, was used to measure average wind speed. Each time the station was visited the average wind speed over a 10 min. period was also measured.

Readings were usually taken from the instruments every 1 - 3 days, at the same time, 10:30 to 11:30 AM, during the period June 9 to August 31, 1976. Hygrothermograph charts were changed monthly. Since vapour pressure deficit (VPD) is more closely related to moisture loss from an organism than is relative humidity (Williams and Brochu 1969) the relative humidity data, adjusted for altitude, were read from the hygrothermograph charts at 6 hr intervals and converted to VPD using the tables of Williams and Leger (1967).

RESULTS

A. PROSPECT MOUNTAIN

Flora

The alpine vascular flora of Prospect Mountain consists of 191 species within 34 families. A complete species list is found in Appendix I. Compositae is the largest family with 26 species, followed by Cruciferae (16 species), Gramineae (16), Cyperaceae (15), Saxifragaceae (12) and Leguminosae (11).

Genera which are particularly species-rich include *Carex, Draba, Saxifraga, Poa, Potentilla, Salix, Erigeron* and *Arnica*. Species-poor genera that are ecologically important include *Dryas, Oxytropis, Hedysarum, Pedicularis* and *Polygonum.*

Both *Dryas integrifolia* and *D. octopetala* are found in the study area and hybrids between the two are common. The hybrids usually resemble *Dryas integrifolia* more closely and were assigned to that taxon for purposes of analysis. *Phyllodoce intermedia*, the hybrid between *Phyllodoce glanduliflora* and *P. empetriformis*, was found in a small clump at a single site although *P. empetriformis* was not in the immediate vicinity. This hybrid is not important ecologically.

The species with the highest presence values are *Androsace chamaejasme* (stand presence = 100%); *Dryas integrifolia, Polygonum viviparum* (90%); *Poa alpina, Salix arctica, Silene acaulis* (81%); *Anemone parviflora* (78%); *Hedysarum alpinum, Potentilla diversifolia* (74%); *Salix nivalis, Pedicularis capitata* and *Solidago multiradiata* (71%).

Phytogeography

The alpine flora of Prospect Mountain is divided into 9 main geographic distribution types. Species which exhibit distributional characteristics of more than one type are assigned to that type which best fits the major part of its range. The annotated species list in Appendix III gives the distributional type for each species.

Arctic-Alpine Species

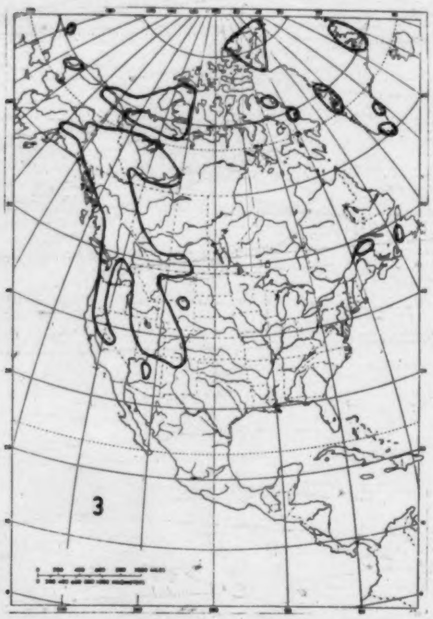
Arctic-alpine species are those restricted to the northern and/or mountainous regions. They occur mainly in, but are not necessarily restricted to, the arctic or alpine habitat; thus they may live in subarctic and mountain forest areas as well. Two types have been recognized for the arctic-alpine species.

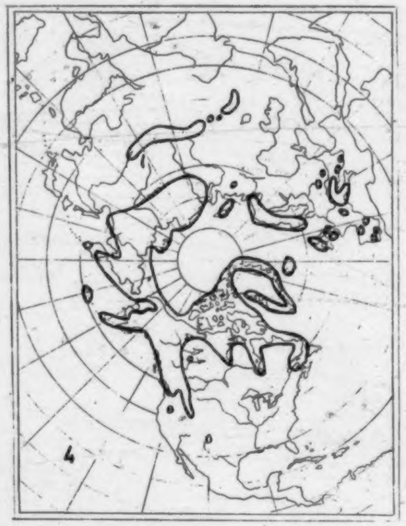
(1) North American Arctic-Alpine (14% of flora)

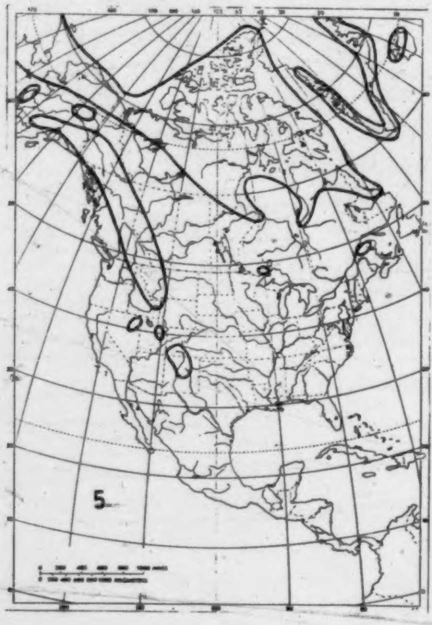
These species are restricted to the arctic and alpine regions of North America. *Erigeron compositus* is an example of this type (Fig. 3). Five species assigned to this type, *Astragalus aboriginum, Anemone parviflora, Pedicularis lanata, Erigeron humilis* and *Parnassia kotzebuei*, are also found in the easternmost islands and mainland areas of Asia, but do not occupy a significant area there.

(2) Circumpolar Arctic-Alpine (25% of flora)

Species of this type, which comprises the largest element of the Prospect flora, are found in the arctic and alpine throughout the northern hemisphere. This distribution may be continuous or not. An example of these circumpolar species is *Saxifraga oppositifolia* (Fig. 4). A number of species in both of these arctic-alpine types have disjunct populations







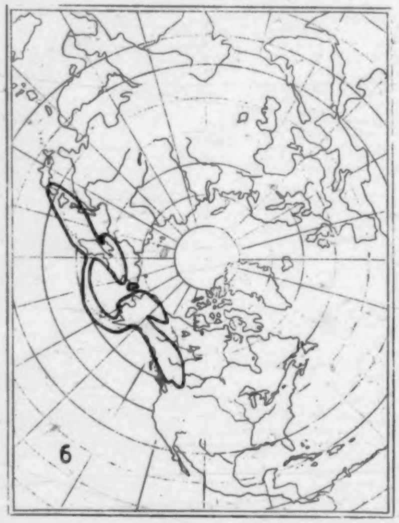


Fig. 3. Distribution of *Erigeron compositus* (Hultén 1968).
Fig. 4. Distribution of *Saxifraga oppositifolia* (Hultén 1968).
Fig. 5. North American distribution of *Saxifraga cernua* (Hultén 1968).
Fig. 6. Distribution of *Campanula lasiocarpa* (Hultén 1968).

in the Great Lakes and/or Gulf of St. Lawrence areas. This disjunct distribution pattern (e.g., *Saxifraga cernua* Fig. 5) has long been known and studied (Fernald 1925, Scoggan 1950, Morisett 1971). A large number of Prospect species fall into one or both of these two categories and are listed in Tables 3 and 4, where the general distribution pattern of each species is added parenthetically.

Amphi-Beringian Species

(3) Amphi-Beringian (6% of flora)

The Amphi-Beringian type includes species found on both sides of the Bering Strait. They exhibit three main distribution patterns, but there are few members in each. The first is comprised of low-elevation and/or widespread North American species which reach only eastern Asia. The second type consists of widespread or northerly Cordilleran species which reach East Asia but no further; *Campanula lasiocarpa* (Fig. 6) has this type of distribution. The third group, typified by *Salix alaxensis* (Fig. 7), includes arctic-alpine species restricted to western North America and eastern Asia, and generally absent from eastern North America and Eurasia.

North American Cordilleran Species

These species are mainly restricted to the western Cordillera and adjacent lowlands in North America. There may be minor disjunctions to the east.

(4) Widespread Cordilleran (13% of flora)

Species of this type, such as *Abies lasiocarpa* (Fig. 8), cover large areas of the Cordillera, usually from Alaska to California or Utah.

Table 3. Arctic and alpine species with Great Lakes disjunction and present in the flora of Prospect Mountain.

Calamagrostis purpurascens (4)*
Phleum alpinum (2)
Poa alpina (2)
Cerastium beeringianum (2)
Epilobium hornemanii (2)
Anemone parviflora (1)
Festuca brachyphylla (2)
Draba crassifolia (1)
Minuartia rubella (2)
Saxifraga cernua (2)
Astragalus alpinus (2)
Draba aurea (2)
Dryas integrifolia (1)

---

* geographic distribution type; see pages 37 - 44.

Table 4. Arctic and alpine species with Gulf of St. Lawrence disjunction and present in the flora of Prospect Mountain.

Lesquerella arctica (1)*
Braya purpurescens (2)
Anemone parviflora (1)
Potentilla nivea (2)
Hedysarum mackenzii (2)
Astragalus aboriginum (1)
Arctostaphylos rubra (2)
Gentianella propinqua (1)
Campanula uniflora (1)
Pedicularis flammea (1)
Erigeron compositus (1)
Taraxacum ceratophorum (2)
Calamagrostis purpurascens (4)
Phleum alpinum (2)
Poa alpina (2)
Luzula spicata (2)
Carex nardina (1)
Kobresia simpliciuscula (2)
Polygonum viviparum (2)
Oxyria digyna (2)
Minuartia rubella (2)
Saxifraga cernua (2)
Saxifraga oppositifolia (2)
Parnassia kotzebuei (1)

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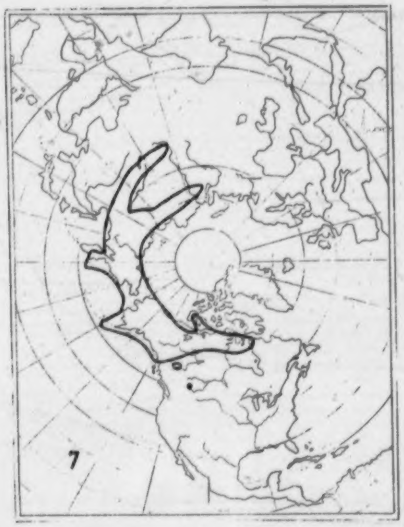
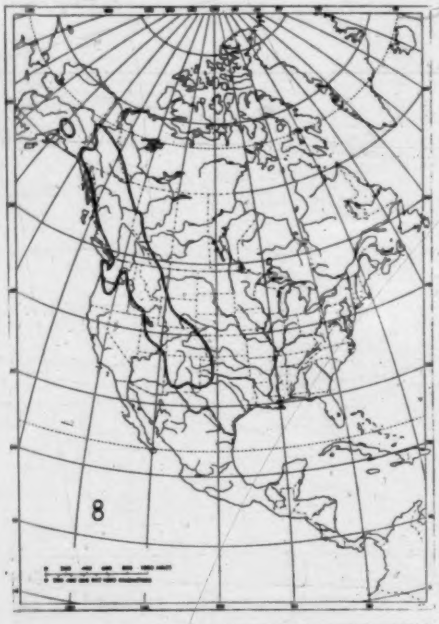
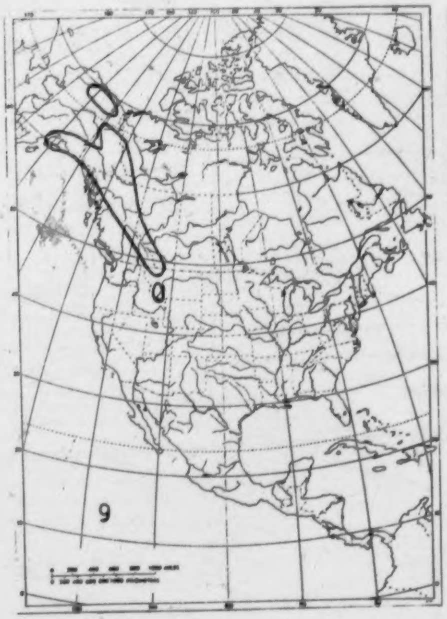
* geographic distribution type; see pages 37 - 44.







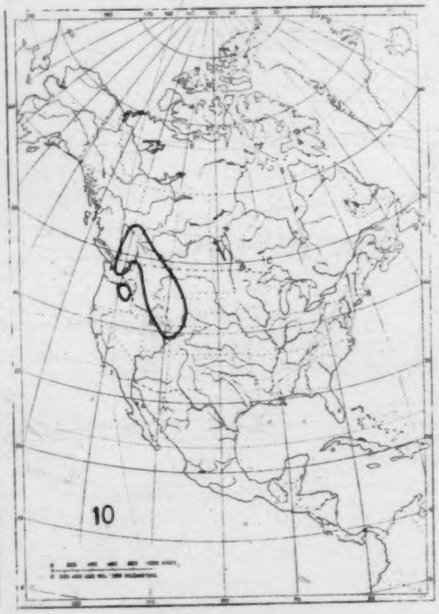


Fig. 7. Distribution of *Salix alaxensis* (Hultén 1968, Porsild 1973). Fig. 8. Distribution of *Abies lasiocarpa* (Hultén 1968). Fig. 9. Distribution of *Salix barrattiana* (Hultén 1968). Fig. 10. Distribution of *Aquilegia flavescens*.

(5) Northern Cordilleran (5% of flora)

The center of distribution for these Cordilleran species is in the north, but they do not occur on the Asian side of the Bering Strait. They generally reach their southern limits in British Columbia or Alberta, although there may be disjunct populations further south. *Salix barrattiana* (Fig. 9) is an example of this type.

(6) Southern Cordilleran (7% of flora)

Species of this type are centered in the southern areas of the Cordillera, e.g. *Aquilegia flavescens* (Fig. 10). Northern limits are usually southern Alberta or British Columbia, but there may be disjunctions further north.

Restricted Rocky Mountain Species

(7) Restricted Rocky Mountain (4% of flora)

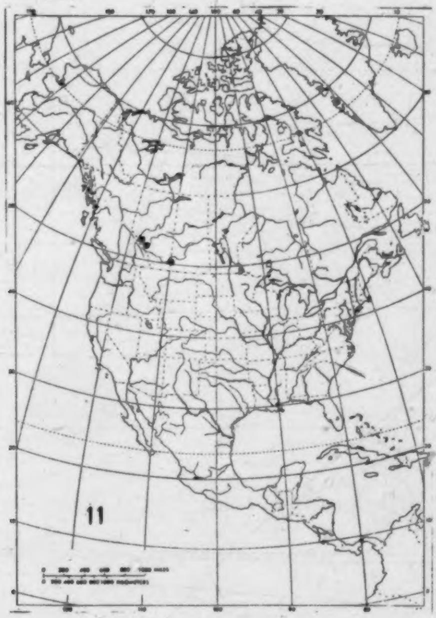
These species are found in localised areas of the Rocky Mountains and adjacent lowlands and could be considered Rocky Mountain endemics. They may occur in only a few sites, e.g. *Erigeron radicatus* (Fig. 11), or may be common throughout their range but restricted latitudinally, e.g. *Saussurea densa* (Fig. 12).

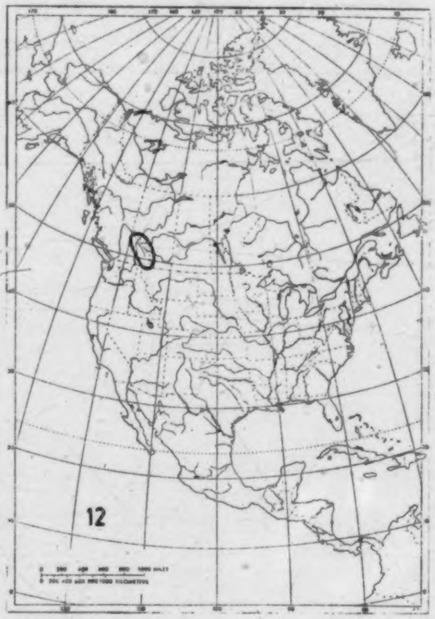
Low-elevation Species

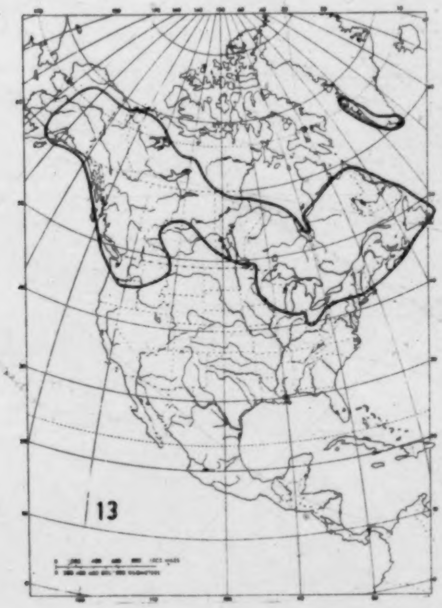
The alpine flora of Prospect Mountain also contains species which are primarily of low-elevation habitats, but that extend high into the mountains. These are usually boreal, but some grassland species are also included. There are two major types.

(8) North American Low-elevation (13% of flora)

These are mainly lower-elevation species, such as *Ledum groenlandicum*







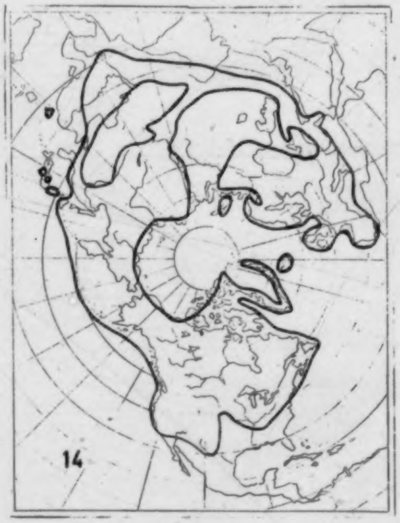


Fig. 11. Distribution of *Erigeron radicatus* (Packer unpubl.). Fig. 12. Distribution of *Saussurea densa* (Packer unpubl.). Fig. 13. Distribution of *Ledum groenlandicum* (Hultén 1968, Packer unpubl.). Fig. 14. Distribution of *Cystopteris fragilis* (Hultén 1968).

(Fig. 13), which may be widespread in North America or in the western part of the continent only.

(9) Circumboreal (14% of flora)

The circumboreal species are widespread throughout the arctic and boreal regions of the northern hemisphere, and may enter some temperate regions as well, e.g. *Cystopteris fragilis* (Fig. 14).

Disjunct Species

Twenty-two species have populations on Prospect Mountain which are notably disjunct from their main centers of distribution (Table 5). They are of particular phytogeographical interest and are therefore examined further.

These species display varying degrees of disjunction. Some are very sporadic or disjunct throughout all or part of their range. *Androsace chamaejasme* (Fig. 15), *Erigeron radicatus* and *Carex franklinii* occur discontinuously throughout most of their ranges. *E. radicatus* is rare, known from only 5 sites, but the others are of more common, albeit scattered, occurrence. Some species have continuous arctic, but scattered alpine distributions, e.g., *Campanula uniflora* (Fig. 16), *Pyrola grandiflora, Papaver kluanensis* and *Kobresia simpliciuscula.*

Of greater phytogeographical significance, though, are those species which exhibit major disjunctions at a single site or localized collection of sites. *Smelowskia calycina, Rumex alpestris* and *Arnica louiseana* have bimodal distributions with one center in the North American or Asian arctic and another in or slightly south of the Alberta Rocky Mountains. For *Smelowskia* (Fig. 17) the major area of distribution is southern, continuous to Waterton, Alberta, and then sporadic north to

Table 5. Species with disjunct occurrences in the flora of Prospect Mountain. Each species is followed by its moisture index and the community types in which it is present.

Carex franklinii 1.5 : 1,6

Kobresia simpliciuscula 2.0 : 7

Papaver kluanensis 1.0 : -

Pyrola grandiflora 2.0 : 7

Androsace chamaejasme 2.5 : 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16

Campanula uniflora 1.5 : 1,4,14

Erigeron radicatus 1.0 : 1,4,14

Carex misandra 2.0 : 1,5,7,14

Carex petricosa 1.5 : 6

Salix alaxensis 3.0 : 2,5,14

Salix reticulata 3.5 : 9,14

Rumex alpestris 4.0 : -

Braya purpurescens 1.0 : 6

Draba macounii 1.0 : 6

Lesquerella arctica 1.0 : 1

Smelowskia calycina 2.0 : 1,2,3,4,7,8,14,16

Telesonix jamesii 1.0 : 4

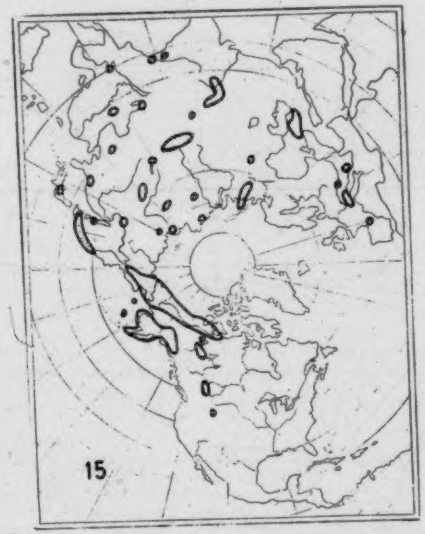
Oxytropis jordalii 3.0 : 14

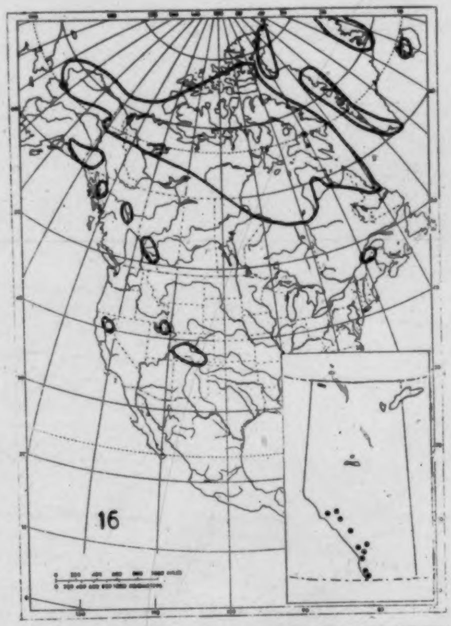
Pedicularis flammea 3.0 : 3,4,7,14

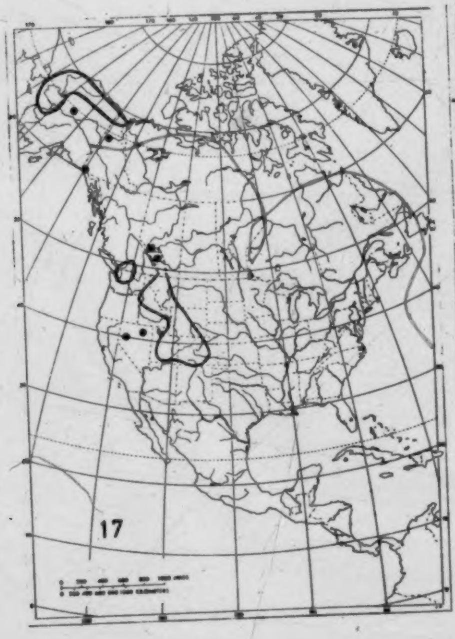
Antennaria monocephala 2.0 : 11

Arnica alpina ssp. *attenuata* 3.0 : 7,9,10,16

Arnica louiseana 2.0 : 4







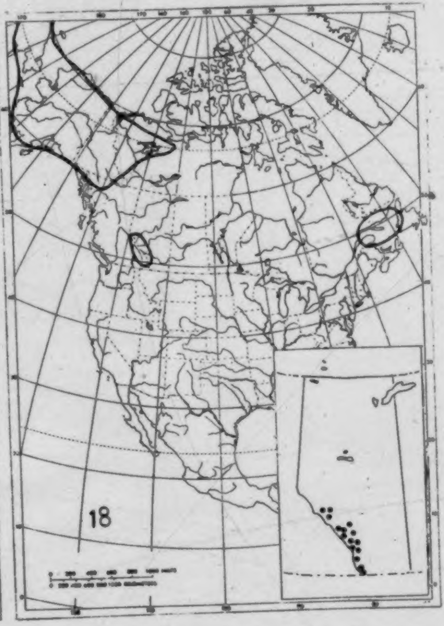


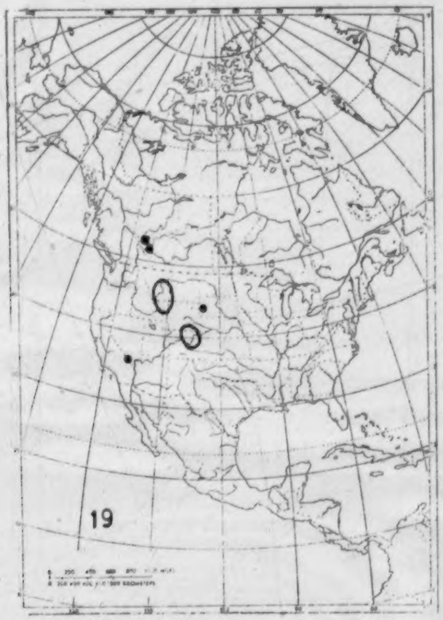
Fig. 15. Distribution of *Androsace chamaejasme* (Hultén 1968). Fig. 16. North American and Alberta distribution of *Campanula uniflora* (Hultén 1968, Packer unpubl.). Fig. 17. North American distribution of *Smelowskia calycina* (Greene 1974, Packer and Vitt 1974). Fig. 18. North American and Alberta distribution of *Arnica louiseana* (Hultén 1968, Packer unpubl.).

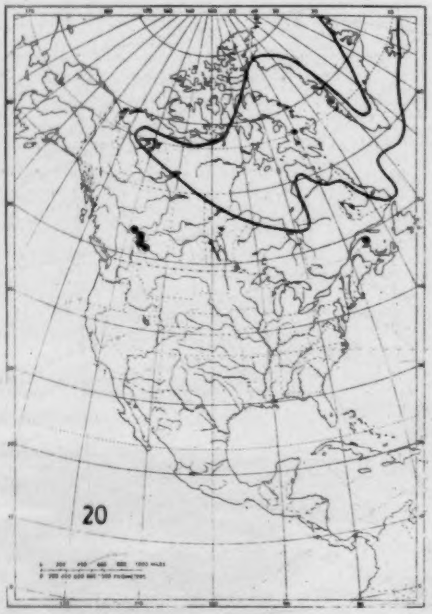
Prospect. *Rumex* and *Arnica* (Fig. 18), however, have their main distribution center in the north, and although they are not uncommon in Alberta, these southern populations are widely disjunct from the more numerous arctic ones.

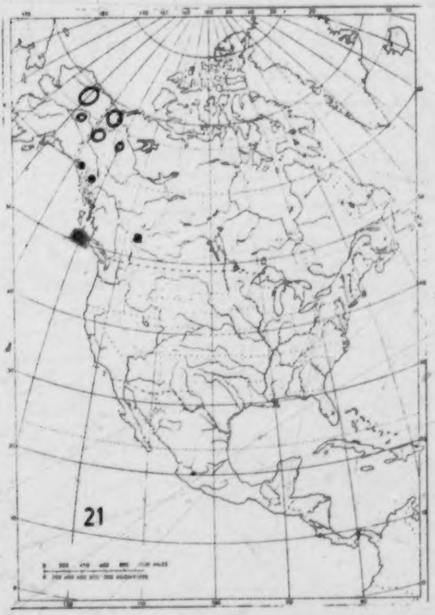
Telesonix jamesii (Fig. 19) has a distribution centered in the southern Rocky Mountains but has two areas of disjunction in the Alberta Rockies, one in the Prospect - Miette Range area (Packer 1974a).

The largest group consists of species which are primarily arctic with one to a few disjunct populations in the Alberta Rocky Mountains. *Pedicularis flammea* (Fig. 20) has a predominantly eastern arctic distribution, with isolated sites in Alberta. Others, such as *Oxytropis jordalii* (Fig. 21), *Carex petricosa, Salix alaxensis* and *Draba macounii* have their major center of continuous distribution in the western arctic, with at least one disjunct population in the Prospect area, and sometimes others. *Braya purpurescens* (Fig. 22), *Carex misandra, Lesquerella arctica, Salix reticulata* and *Arnica alpina* ssp. *attenuata* are widespread in the Canadian arctic with alpine disjunctions to the south, including Prospect Mountain.

Distributional disjunctions may result from habitat disjunction and/or historical factors. Therefore the possibility of specialized environmental requirements for these species must be studied. The disjunct species on Prospect were found in a number of habitats, from windswept rocky peaks for *Papaver kluanensis* and dry rocky ledges for *Telesonix jamesii*, to lush moist meadows where *Salix alaxensis* and *Oxytropis jordalii* are common. The variety of habitats is shown in Table 5 which gives the moisture index (MI) assigned to each species as well as lists the community types (ct's) in which they were found







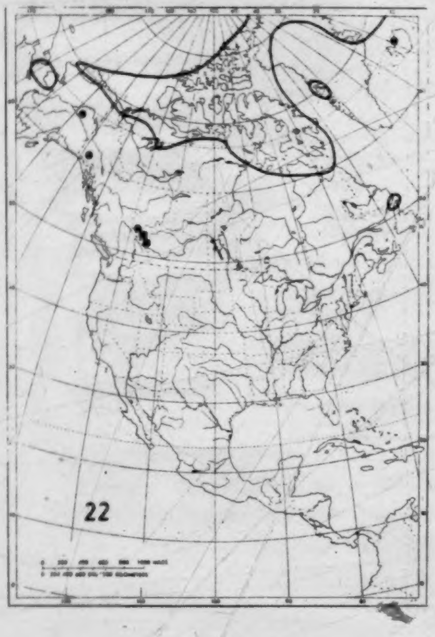


Fig. 19. Distribution of *Telesonix jamesii* (Packer and Vitt 1974). Fig. 20. North American and Alberta distribution of *Pedicularis flammea* (Packer and Vitt 1974, Packer unpubl.). Fig. 21. Distribution of *Oxytropis jordalii* (Elisens 1978). Fig. 22. North American distribution of *Braya purpurescens* (Packer and Vitt 1974).

(for an explanation of MI see page 31; for ct desriptions see page 60).

Androsace chamaejasme is a ubiquist, present in all ct's. *Smelowskia calycina* is also widespread. *Rumex alpestris* and *Papaver kluanensis* were collected on the mountain but were not sampled in any recognised ct. The rest of the disjunct species were found in one to a few ct's. Of the numerous ct's in which disjuncts are found, ct's 1 and 14 are most common. Ct 1 is the dry, species-poor *Dryas integrifolia - Carex rupestris* rock stripe community, and ct 14 the mesic *Dryas integrifolia - Hedysarum alpinum* meadow community.

The species MI's range from 1 to 4 (xeric to mesic), although the xeric end is more common, especially with the rarer, more widely disjunct arctic species.

The disjunct species occur over a fairly wide range of pH's as well. *Antennaria monocephala*, *Kobresia simpliciuscula* and *Salix reticulata* are found in neutral to slightly acidic soil, while *Erigeron radicatus*, *Lesquerella arctica*, *Telesonix jamesii* and *Campanula uniflora* are present on basic, highly calcareous soils. *Androsace chamaejasme* tolerates the entire spectrum of pH available (i.e. 5.6 to 8.1).

Vegetation

Cluster Analysis

Cluster analysis dendrograms may be examined at any level using two approaches, i.e. at a specified level of significance for the coefficient, or the level at which a specified number of clusters are formed. The latter approach was utilized in this study as the coefficient ranges for the hierarchy based on presence-absence data (qualitative), and that based on PV's (quantitative) are not of the same magnitude. The coefficients for the quantitative cluster levels were higher, indicating greater dissimilarity in species structure as compared to species composition for the various stands. Therefore both the quantitative and qualitative cluster hierarchies were analysed at the 8-cluster level, at coefficients 1.169 and 0.171 respectively (Fig. 23, Fig 24).

The qualitative cluster dendrogram proved less useful in the classification of the vegetation than the quantitative one, as the prominent species, which are most important in community classification, are weighted in the quantitative analysis. The qualitative cluster dendrogram, however, does illustrate compositional similarities very well. Stands 22 and 25 are quite distinct floristically, remaining unclustered even at the 8-cluster level. These 2 stands possess the highest species richness recorded. Other compositionally distinct stands, i.e. those unclustered at low coefficient levels, are 5, 19, 27 and 28. Stands 1-4, 10 and 17 cluster early to form a group with homogeneous composition.

The qualitatively based cluster analysis can be used in conjunction with the quantitatively based one to identify groups of stands, similar in both species composition and species structure, to provide a basis for classification. The quantitatively based dendrogram contains 2 primary clusters, *Dryas integrifolia*-dominated stands on the left, and the remainder on the right (Fig. 24). The latter cluster consists of 5 well-separated secondary clusters at the 8-cluster level, including stands dominated by *Phyllodoce glanduliflora* (12, 15), *Cassiope tetragona* (13, 14, 23), *Salix arctica* (30, 31), *Salix barrattiana* (16, 25), and the lush herb meadows (27, 28). These divisions are not

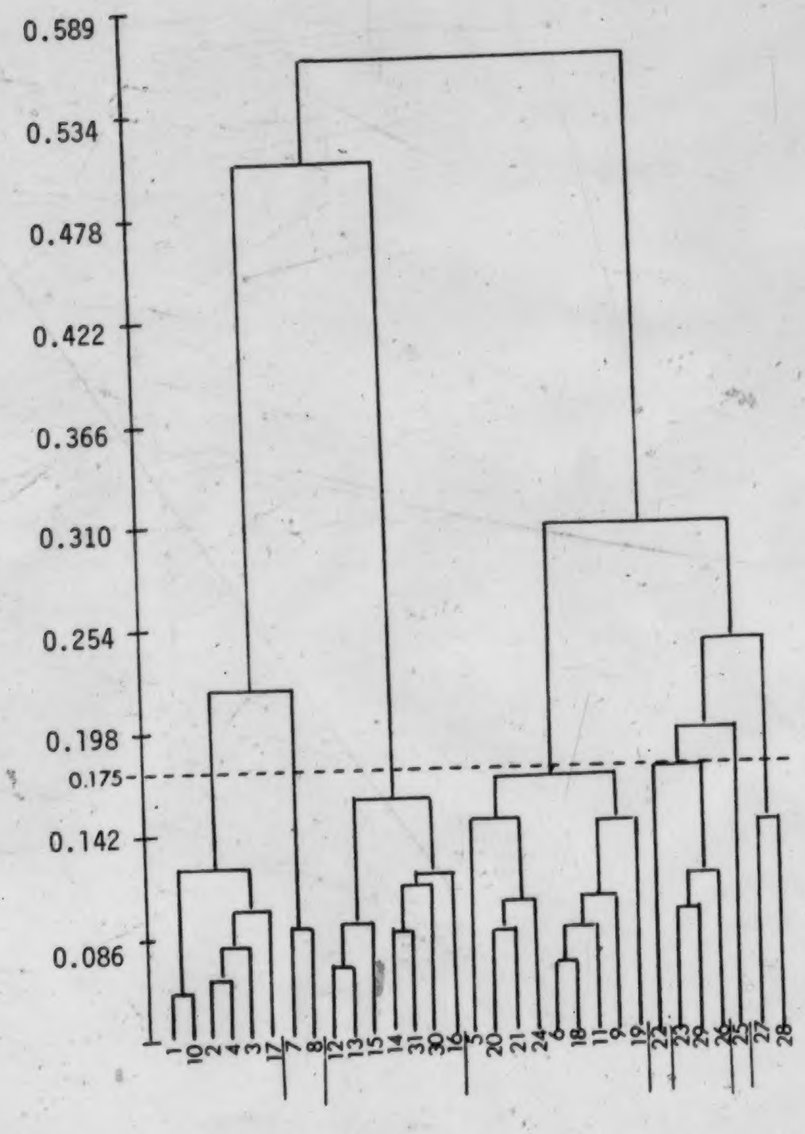


Fig. 23. Qualitatively based cluster dendrogram with 8-cluster level marked.

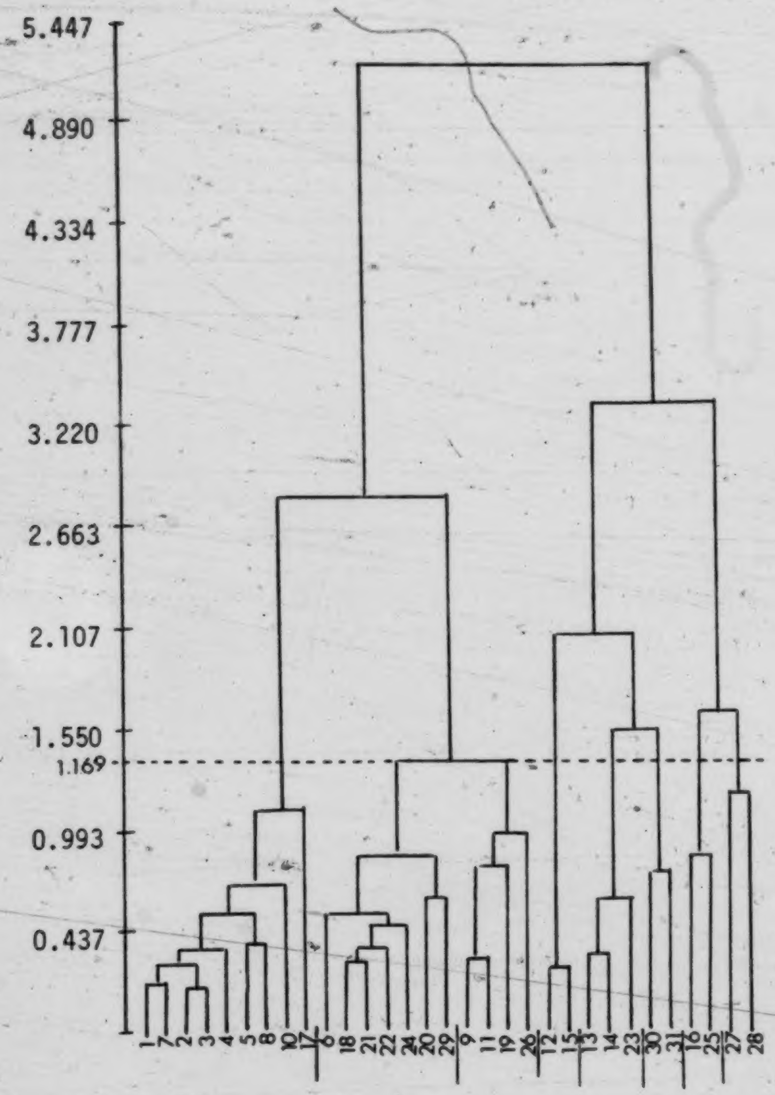


Fig. 24. Quantitatively based cluster dendrogram with 8-cluster level marked.

clear in the qualitative dendrogram.

The *Dryas*-dominated stands form 3 secondary clusters at the 8-cluster level. The first (stands 1-5, 7, 8, 10, 17) is very similar to the first 2 clusters based on composition (Fig. 23), and thus consists of floristically and structurally similar *Dryas*-dominated stands. The second cluster (6, 18, 21, 22, 24, 20, 29) is compositionally variable and requires further examination before assignment to a single classification unit. Stands of the final secondary cluster (9, 11, 19, 26) are characterized by significant shrub cover. Stand 26 is widely separated from the other members of this group in the qualitatively based dendrogram, suggesting significant differences in species composition.

Ordination

Indirect Bray-Curtis ordination of Prospect stands was constructed using the quantitative data (see METHODS, page 30), but the results gave little added insight to the vegetation classification. The ordinations also failed to clearly show the major environmental gradients along which the stands were placed. Therefore the indirect ordination results for the Prospect stands alone are not presented in this thesis.

Classification

Using the cluster analyses, similarity matrices and field observations, the alpine vegetation of Prospect Mountain was classified into 16 community types (ct's) within 5 major groups (Table 6). Of these 5 groups, 4 are those designated by Hrapko and La Roi (1978): Rock Tundra, Heath Tundra, Meadow Tundra and Snowbed Tundra. The final group, Shrub Tundra, includes plant communities dominated by low shrubs such as

Table 6. Classification hierarchy of alpine tundra groups and community types for the Prospect Mountain study area.

I. Rock Tundra Group
   1. *Dryas integrifolia - Carex rupestris* type (1,2,3)*
      a. *Arctostaphylos uva-ursi* subtype (4)
   2. *Dryas integrifolia - Salix alaxensis* (islands) type (7)
   3. *Dryas integrifolia - Salix arctica* type (8)
   4. *Dryas integrifolia - Oxytropis podocarpa* type (18)
      a. *Kobresia bellardii* subtype (21)
      b. sandstone outcrop subtype (5)
   5. *Dryas integrifolia - Cassiope tetragona* type (10)
   6. *Dryas integrifolia - Hedysarum mackenzii* type (17)

II. Shrub Tundra Group
   A. Shrub Stripe Subgroup
      7. *Dryas integrifolia - Betula glandulosa* type (9,11)
         a. *Dryas* - shrub subtype (19)

   B. Willow Scrub Subgroup
      8. *Salix arctica - Hedysarum alpinum* type (30)
      9. *Salix* spp. - *Cassiope tetragona* type (26)
      10. *Salix barrattiana - Trollius albiflorus* (16,25)

III. Heath Tundra Group
   11. *Cassiope tetragona - Dryas octopetala* type (13,14)
      a. *Cassiope - Salix nivalis* subtype (23)
   12. *Phyllodoce glanduliflora - Cassiope mertensiana* type (12,15)

IV. Snowbed Tundra Group
   13. *Salix arctica - Salix nivalis* type (31)

V. Meadow Tundra Group
   A. *Dryas* Meadow Subgroup
      14. *Dryas integrifolia - Hedysarum alpinum* type (6,22,24,29)
         a. *Salix alaxensis* subtype (20)

   B. Herb Meadow Subgroup
      15. *Elymus innovatus - Mertensia paniculata* type (27)
      16. *Artemisia norvegica - Aquilegia flavescens* (28)

---

* stand numbers

Betula glandulosa and *Salix* spp.. The partial similarity matrices for each group are shown in Fig. 25; the complete matrix is in Appendix II.

The Rock Tundra Group covers the largest area, forming the matrix in which the other groups occur. Its communities cover a variety of aspects and altitudes, but are found mainly on exposed ridgetops and steep slopes. This group is characterized by extensive bare ground, rock rubble and large boulders; the mean cover of unvegetated ground in the group is 53%. Associated are numerous periglacial features, such as polygons, stripes and terraces. There is virtually no soil development; Orthic and Orthic Humic Regosols predominate. All the ct's are dominated by *Dryas integrifolia*, often overwhelmingly. Other common species are *Polygonum viviparum, Carex rupestris, Androsace chamaejasme* and *Oxytropis podocarpa.* Lichens are more common than mosses, but both are low in cover. This group is divided into 6 ct's with 3 subtypes (st's). It is a homogeneous group with high similarity between its member stands ($\bar{x}$ IS = 48%; Fig. 25).

The Shrub Tundra Group is a more heterogeneous assemblage, encompassing a variety of communities with a single shrub or mixture of shrub species dominant. Physiognomically it ranges from low (< 20 cm) shrub stripes to scrub thickets of medium height (30 - 150 cm). Shrub Tundra is generally found on gentle slopes with NE or NW exposures, from treeline to 2065 m ASL. Soils are Orthic Humic and Cumulic Humic Regosols. There are 2 distinct subgroups, Shrub Stripes and Willow Scrub. The Shrub Stripes closely resemble many Rock Tundra communities. Although dominated by *Dryas integrifolia*, shrub species are next in cover and contribute strongly to community physiognomy. Bare ground cover is low ($\bar{x}$ = 8%) but conspicuous rock stripes and terraced topography

Fig. 25. Similarity matrices for the major community groups.

Rock Tundra stands

	1	2	3	4	5	7	8	18	21	10	17
1		19	81	89	64	61	38	80	74	56	46
2			17	21	23	24	7	11	10	9	8
3				87	53	56	35	80	64	63	55
4					61	66	41	77	71	57	49
5						87	61	58	54	35	27
7							62	53	52	35	28
8								35	34	22	35
18									77	34	47
21										47	39
10											76
17											

$\bar{x}$ IS = 48%
$\bar{x}$ IS(1,2,3,4) = 82%
$\bar{x}$ IS(18,21,5) = 63%

Heath Tundra stands

	12	15	13	14	23
12		61	7	6	9
15			5	4	10
13				79	65
14					64

$\bar{x}$ IS = 31%
$\bar{x}$ IS(13,14,23) = 69%
$\bar{x}$ IS(12,15) = 61%

Shrub Tundra stands

Shrub Stripes

	9	11	19
9		74	67
11			63

$\bar{x}$ IS = 68%

Willow Scrub

	30	31	26	25	16
30		42	35	12	10
31			26	6	6
26				17	13
25					86

$\bar{x}$ IS = 29%

Meadow Tundra stands

Dryas Meadow

	29	22	6	24	20
29		78	62	55	76
22			70	8	79
6				76	68
24					57

$\bar{x}$ IS = 63%

Herb Meadow

	27	28
27		11

$\bar{x}$ IS = 11%

underlie the plant cover. Mosses are significant, especially under the *Betula* stripes where their cover equals that of the vascular plants. This subgroup has 1 ct and 1 st. Communities of the Willow Scrub Subgroup are dominated by *Salix* spp.. They are most often found at the bases of slopes or in protected sites, fed by meltwater, or in deep snow accumulation hollows. This subgroup is very heterogeneous ($\bar{x}$ IS = 29%) as the dominant *Salix* sp. or spp. vary. The subgroup has 3 ct's.

Heath Tundra communities are mainly restricted to hollows on the SE and E sides of the mountain. The hollows are surrounded by low krummholz of *Abies lasiocarpa* and *Picea engelmanii* with scattered *Salix vestita*. Community placement is in concentric rings and correlated with snow release date, with *Cassiope tetragona* in the early release areas and *Phyllodoce glanduliflora* and *Cassiope mertensiana* in areas of deeper snow accumulation. Two ct's and 1 st are found in this group. Numerous subalpine species occur here including *Aquilegia flavescens*, *Moneses uniflora* and *Erigeron peregrinus*. The soils are well developed; Melanic and Eutric Brunisols are found in association with Orthic Regosols.

Snowbed communities are few and of limited extent on the mountain. They occur most commonly on S- or E-facing slopes in depressions or in the lee of ridges. They melt out later than the heath hollows, as late as mid-August in some cases. Because of this, snowbeds are always low in plant cover and are poorly developed. Soils are thin Orthic Humic Regosols. One ct is described for this group.

The Meadow Tundra Group, characterized by high plant cover with a continuous or discontinuous layer of tall herbs, occupies large areas on NW- and NE-facing slopes but is found in smaller patches elsewhere.

A very heterogeneous group ($\bar{x}$ IS = 35%), it is divided into 2 subgroups. The *Dryas* Meadow Subgroup consists of 1 ct and 1 st dominated by *Dryas integrifolia*. Above the continuous *Dryas* and moss layer, taller herbs such as *Hedysarum alpinum*, *Elymus innovatus* and *Oxytropis* spp. form a more discontinuous layer. In contrast, the 2 communities of the Herb Meadow Subgroup are dominated by these tall herbs, and *Dryas* is much less common. They are found in areas where water is in constant supply. Soils for the entire group are Orthic and Orthic Humic Regosols. Species composition is highly variable within the group, with *Hedysarum alpinum* having the highest constancy.

Figure 26 shows the final classification hierarchy (Table 6) superimposed on the cluster fusion hierarchy. The greatest correspondence occurs at the lower levels. A few stands appear to be misplaced, though. Stands 18 and 21 show high similarity to the *Dryas* Meadow Subgroup, probably due to the higher herb and total plant cover here than for most Rock Tundra communities. Stand 26 of the Willow Scrub Subgroup appears closer to the members of the Shrub Stripe Subgroup. A possible explanation is the large number of shrub species present, in addition to *Salix* spp., as is common in the Shrub Stripes. The *Salix arctica* - - *Hedysarum alpinum* ct (stand 30) clusters more closely to the Snowbed community because of the coincidence of dominant species, although structurally and compositionally they are quite distinct. The internal heterogeneity of the Willow Scrub Subgroup and the Meadow Tundra Group are shown by the separation of their component parts at higher fusion levels in the dendrogram.

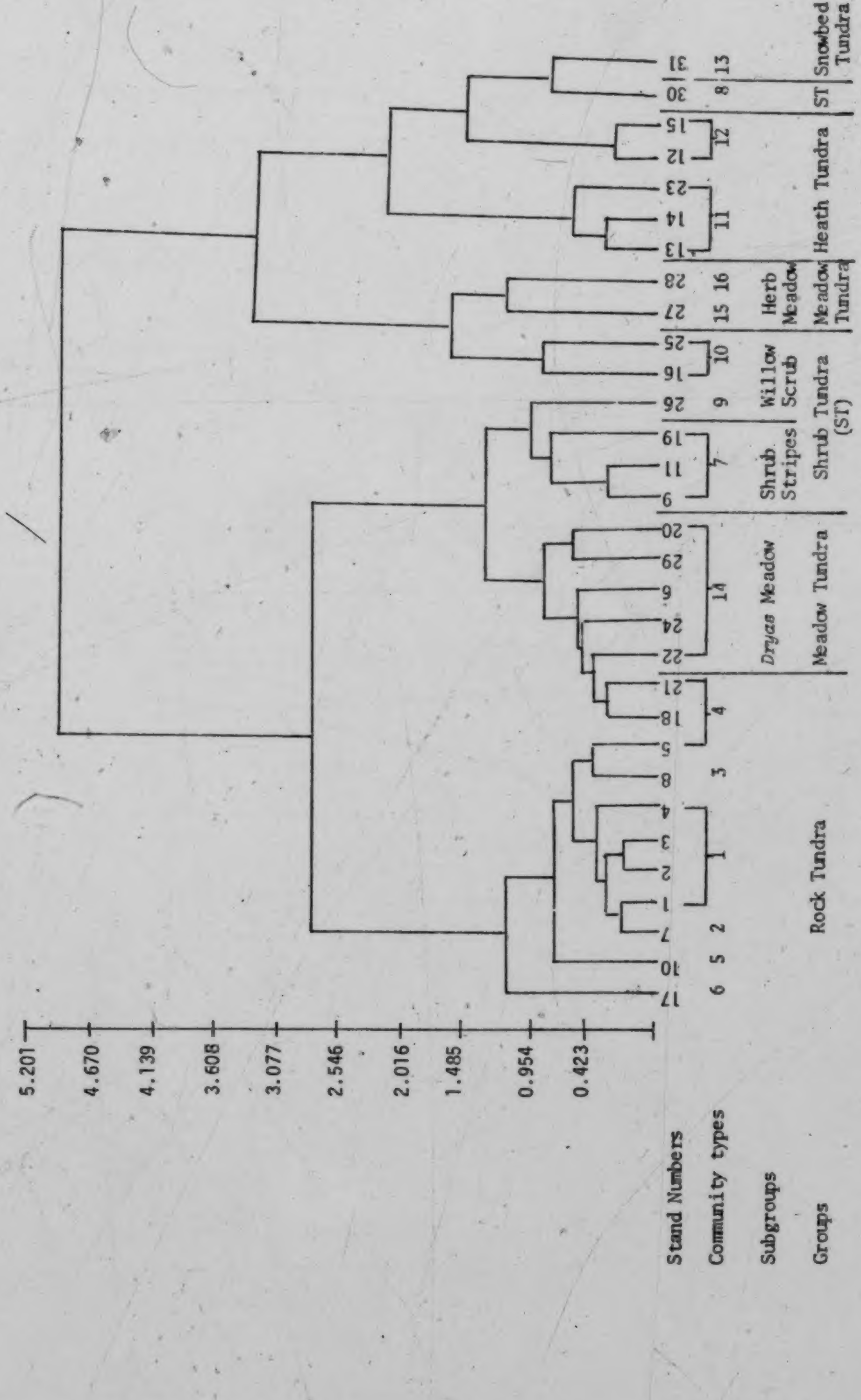


Fig. 26. Quantitatively based cluster dendrogram showing classification hierarchy (see Table 6, page 54).

Community Descriptions

Rock Tundra Group (Table 7)

1. *Dryas integrifolia* - *Carex rupestris* community type (stands 1,2,3)

The *Dryas integrifolia* - *Carex rupestris* ct covers a large area, mostly on N-facing slopes and ridgetops, but on some S-facing slopes as well. *Dryas integrifolia* is dominant in all cases and *Carex rupestris* is usually next in importance.

On the steeper slopes the plant cover forms vegetation stripes perpendicular to the contours of the slope. These stripes are very regular in size with the rock and vegetation bands both .5 - 1 m wide. The rock stripes are composed mainly of colluvial calcareous material varying in size from pebbles to boulders. Individual vascular plants do manage to become established in this rock rubble, especially *Carex rupestris*, *Saxifraga oppositifolia*, *Pedicularis lanata* and *Saxifraga aizoides*.

Between the rock stripes *Dryas integrifolia* forms the matrix of the vegetation stripes. *Polygonum viviparum* and *Androsace chamaejasme* are common throughout, but are low in cover. Legumes are also significant with *Oxytropis podocarpa* more important on N-facing slopes and *O. campestris* more so on S-facing slopes. A number of species are found only in this ct of the Rock Tundra, including *Erigeron radicatus*, *Braya humilis*, *Draba porsildii*, *Lesquerella arctica* and *Campanula rotundifolia*. The genus *Draba* is particularly rich in this ct with 5 of the 7 species found in the Rock Tundra.

Not all the stripes are flat. Some are stepped with a sloping vegetation stripe joining the level rock stripes. At these sites the

Table 7. Selected site and community attributes of stands of the Rock Tundra Group. See Table 6 (page 54) for names of community types.

	ct 1				ct 2	ct 3	ct 4			ct 5	ct 6
	stand 1	stand 2	stand 3	stand 4	stand 7	stand 8	stand 18	stand 21	stand 5	stand 10	stand 17
Date	July 7	July 8	July 8	July 8	July 10	July 10	July 26	July 30	July 9	July 10	July 26
Altitude (m)	2057	2143	2131	2082	2124	2115	2073	2070	2121	2051	2048
Slope (°)	30	11:15	22	18	34	32	21	28	19	19	10
Aspect	N	NW:SE	SE	E	NE	NE	NE	NW	N	NW	NE
Soil type**	O.HR.	O.R.	O.HR.	O.HR.	O.R.	O.R.	O.R.	O.HR.	O.HR.	O.HR.	O.HR.
Surface pH	7.7	7.9	8.0	7.7	7.4	7.4	7.5	7.5	6.8	7.5	7.4
% coarse fraction	69	97	43	77	47	49	43	55	83	50	20
% available moisture (< 2 mm)	13	7	11	12	15	10	16	15	9	26	18
No. quadrats	30	30	30	30	30	30	30	30	30	30	30
No. vascular species	25	20	31	20	33	37	39	44	44	29	32
NSQ	5	1	4	4	2	3	5	6	3	7	5
$\bar{x}$ cover (%) -											
vascular species	35	5	39	43	19	20	42	47	28	65	76
mosses	1	0.1	0.2	0.3	5	5	16	32	5	13	1
lichens - saxicolous	2	1	1	1	0.4	1	1	1	0.4	0.3	0.1
terricolous	10	1	32	3	1	1	2	5	1	5	4
bare ground	49	86	56	50	77	74	45	34	64	28	16
PV vascular species -											
Dryas integrifolia	240	20	288	239	132	82	279	229	129	512	653
Carex rupestris	22	12	28	17	0.3	-	1.8	0.03	2.1	13	18
Polygonum viviparum	0.7	0.03	0.6	3.8	2.3	1.4	24	5.8	-	3.3	2.7
*Androsace chamaejasme**	0.3	0.03	4.4	4.1	0.4	0.03	1.2	0.5	0.2	1.0	3.9
Carex nardina	1.4	+	+	2.0	0.03	+	0.03	-	-	+	+
Silene acaulis	1.9	+	+	-	0.9	+	-	+	+	4.7	+
Pedicularis lanata	1.4	+	+	+	0.9	-	0.03	-	-	0.4	0.03
Anemone parviflora	0.3	-	0.03	-	0.1	0.1	0.03	+	-	0.1	0.6
Antennaria alpina	-	+	0.5	0.1	-	+	-	+	+	0.03	-
Potentilla fruticosa	-	-	0.1	0.1	-	-	2.2	+	+	-	+
Draba incerta	+	-	+	-	+	0.03	0.03	-	-	-	-
Aster alpinus	-	-	+	0.6	-	-	0.03	0.9	+	-	0.1
Saxifraga oppositifolia	14	0.5	0.6	1.2	1.2	-	-	+	-	3.2	0.5
Oxytropis campestris	-	0.3	8.6	2.8	-	-	0.7	2.4	0.6	-	+
Draba lonchocarpa	-	+	0.03	-	0.1	0.03	-	-	-	-	-
Saxifraga aizoides	0.4	-	-	-	-	-	-	-	-	-	+
*Lesquerella arctica**	-	0.03	0.1	0.03	-	-	-	-	-	-	-
*Carex franklinii**	-	-	+	-	-	-	-	-	-	-	+
*Carex petricosa**	-	-	+	-	-	-	-	-	-	-	-
*Carex misandra**	+	-	-	-	-	-	-	-	0.03	-	-
Selaginella densa	-	+	-	-	+	-	-	-	-	-	-
Braya humilis	-	+	-	-	-	-	-	-	-	-	-
Draba porsildii	-	+	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	-	+	-	-	-	-	-	-	-	-
Minuartia rubella	-	-	+	-	-	-	0.03	-	-	-	-

Table 7. (cont.)

	ct 1				ct 2	ct 3	ct 4			ct 5	ct 6
	stand 1	stand 2	stand 3	stand 4	stand 7	stand 8	stand 18	stand 21	stand 5	stand 10	stand 17
Draba cana	-	-	+	-	-	-	-	+	-	-	-
Draba oligosperma	-	-	+	-	-	-	-	-	+	-	-
Arctostaphylos uva-ursi	+	-	-	101	-	-	-	-	-	-	-
Erigeron radicatus	-	-	-	0.03	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	1.2	0.5	-	0.1	+	-	-
Salix alaxensis	-	-	-	-	0.9	-	-	-	1.1	-	-
Saxifraga caespitosa	-	-	-	-	+	+	-	-	-	-	-
Taraxacum ceratophorum	-	-	-	-	+	-	-	-	0.03	-	-
Festuca brachyphylla	-	-	-	-	+	-	-	+	0.03	-	-
Oxyria digyna	-	-	-	-	+	-	-	-	-	-	-
Cystopteris fragilis	-	-	-	-	+	-	-	-	-	-	-
*Draba macounii**	-	-	-	-	+	-	-	-	-	-	-
Salix arctica	+	+	-	-	0.1	28	+	1.1	-	0.1	-
Astragalus alpinus	-	-	+	-	-	10	-	-	-	-	-
Dryas octopetala	-	-	-	-	-	3.5	-	-	+	-	-
Poa alpina	-	-	-	-	-	1.2	0.2	0.6	+	-	+
Epilobium latifolium	-	-	-	-	0.03	1.1	-	-	-	-	-
Minuartia austromontana	-	-	-	-	+	0.6	+	-	-	-	-
Lychnis apetala	-	-	-	-	0.03	0.1	-	-	-	-	-
Equisetum scirpoides	-	-	-	-	-	+	-	-	-	0.03	-
Cerastium beeringianum	-	-	-	-	-	+	-	-	-	-	-
Androsace septentrionalis	-	-	-	-	-	+	-	-	-	-	-
Castilleja occidentalis	-	-	-	-	-	+	-	-	-	-	-
Erigeron lanatus	-	-	-	-	-	+	-	-	-	-	-
Oxytropis podocarpa	28	-	+	-	0.6	1.3	35	62	18	9.1	+
Kobresia bellardii	-	-	-	-	-	-	10	59	-	11	0.03
Hedysarum alpinum	-	-	-	-	-	-	7.0	15	0.03	-	+
Saxifraga tricuspidata	-	-	-	-	+	2.2	3.1	0.4	4.2	-	-
Pedicularis capitata	+	+	-	-	0.5	+	0.3	4.4	-	0.03	-
Festuca baffinensis	-	-	-	-	0.3	0.03	0.03	0.8	-	-	-
*Smelowskia calycina**	+	-	-	-	0.2	0.03	1.5	3.9	+	-	-
Solidago multiradiata	-	-	+	-	-	-	0.1	-	0.2	0.03	-
Anemone drummondii	-	-	-	-	+	+	0.1	0.4	0.3	-	-
*Pedicularis flammea**	-	-	-	-	-	+	0.03	+	-	-	-
Potentilla diversifolia	-	-	-	-	-	+	0.6	+	0.5	-	-
Myosotis alpestris	-	-	-	-	-	+	0.3	0.03	+	-	-
Potentilla nivea	-	-	+	-	-	-	1.2	1.2	+	-	-
Trisetum spicatum	-	-	-	-	-	-	+	3.2	+	-	-
Arnica alpina	-	-	-	-	-	-	2.1	0.5	+	-	+
Bromus pumpellianus	-	-	-	-	-	-	0.6	1.4	+	-	-
Delphinium glaucum	-	-	-	-	-	-	+	0.6	0.03	-	-
Potentilla diversifolia var. *multisecta*	-	-	-	-	-	-	0.03	0.03	+	-	-

Table 7. (cont.)

	ct 1				ct 2	ct 3	ct 4			ct 5	ct 6
	stand 1	stand 2	stand 3	stand 4	stand 7	stand 8	stand 18	stand 21	stand 5	stand 10	stand 17
Gentiana prostrata	-	-	-	-	-	-	+	0.03	-	-	-
*Arnica louiseana**	-	-	-	-	-	-	-	+	0.03	-	-
Elymus innovatus	-	-	-	-	-	-	-	+	+	-	+
Aconitum delphinifolium	-	-	-	-	-	-	-	+	+	-	-
Betula glandulosa	-	-	-	-	-	-	+	-	-	-	+
Senecio lugens	-	-	-	-	-	-	+	-	-	-	-
Astragalus vexilliflexus	-	-	-	-	-	-	-	2.6	-	-	-
Gentianella propinqua	-	-	-	-	-	-	-	0.4	-	-	-
Poa pattersonii	-	-	-	-	-	-	-	0.1	-	-	-
Poa arctica	-	-	-	-	-	-	-	+	-	-	-
Calamagrostis purpurescens	-	-	-	+	+	-	-	-	2.1	-	+
Potentilla uniflora	+	+	-	+	-	-	+	-	1.4	-	-
*Campanula uniflora**	+	+	-	+	-	-	+	-	1.4	-	-
Erigeron compositus	-	-	-	-	-	+	+	+	1.1	-	-
Saussurea densa	+	-	-	-	0.1	0.03	-	+	0.6	+	-
Eriogonum androsaceum	-	-	+	-	-	-	-	-	0.1	-	-
Astragalus aboriginum	-	-	-	-	-	-	-	-	0.2	-	-
Senecio canus	-	-	-	-	-	-	-	-	0.1	-	-
Botrychium lunaria	-	-	-	-	-	-	-	-	+	-	-
*Telesonix jamesii**	-	-	-	-	-	-	-	-	+	-	-
Draba paysonii	-	-	-	-	-	-	-	-	+	-	-
Cassiope tetragona	+	-	-	-	-	-	-	-	-	67	+
Salix vestita	+	-	-	-	-	-	-	-	+	13	+
Tofieldia pusilla	-	-	-	-	-	-	-	-	-	7.0	-
Arctostaphylos rubra	+	-	+	+	-	+	-	-	-	4.2	+
Salix nivalis	1.2	-	-	-	+	1.4	1.8	-	0.03	3.4	-
*Pyrola grandiflora**	-	-	-	-	-	-	-	-	-	0.3	-
Carex atrosquama	-	-	-	-	-	-	-	-	-	+	+
Carex raymondii	-	-	-	-	-	-	-	-	-	+	-
Hedysarum mackenzii	0.5	+	9.2	2.5	-	-	-	-	-	23	122
Carex scirpoidea	+	-	+	0.03	-	-	-	-	-	-	7.1
Zygadenus elegans	-	-	-	0.03	-	-	+	-	-	-	0.5
Ledum groenlandicum	-	-	-	-	-	-	-	-	-	-	+

* disjunct species

** Soil types: O.HR. (Orthic Humic Regosol), O.R. (Orthic Regosol)

*** mean number of species per 25 X 25 cm quadrat

+ present in community but not in quadrats plant cover is thicker and dwarf shrubs such as *Salix arctica* and *Arctostaphylos rubra* are present in small amounts.

On the windswept ridgetops the stripe pattern breaks down and plants exist only as scattered individuals (stand 2).

Total vascular plant cover for this community type is low ($\bar{x}$ = 26%). Although the average number of species per stand is 25, many of these have low PV's or are simply present. In general, lichen and moss cover is low as well.

There is little soil development under this community. The soils are Orthic or Orthic Humic Regosols with shallow profiles, high pH and a large percent coarse fraction.

This is the most common ct on Prospect and is present on all ridges, both as small patches and as large expanses covering entire slopes.

Although *Oxytropis podocarpa* has the second highest PV in stand 1, *Carex rupestris* is a close third and is more diagnostic. The placement of this stand in the *Dryas* - *Carex rupestris* ct is reinforced by the high similarity it exhibits with others of this type: 81% with stand 3, 89% with subtype stand 4. Stand 2 shows low similarity with all stands, perhaps due to the very low PV's of all its species.

1a. *Arctostaphylos uva-ursi* subtype (stand 4)

In restricted areas on the S-facing slope of R3, the rock stripes grade into distinct terraces .2 - 1 m high, dominated by *Arctostaphylos uva-ursi*. The amount of *Arctostaphylos* varies from scattered plants on the lower terraces to continuous mats on the higher ones, but it has a high PV for the stand. In areas where *Arctostaphylos* cover is continuous, individual plants of such species as *Zygadenus elegans*, *Hedysarum*

Plate 4. The *Dryas integrifolia - Carex rupestris* community (ct 1) forming slightly banked vegetation stripes on the N--facing slope of R2. The old mining road can be seen in the background, as well as a pile of overburden left from the coal mining operations. (July 6, 1976)

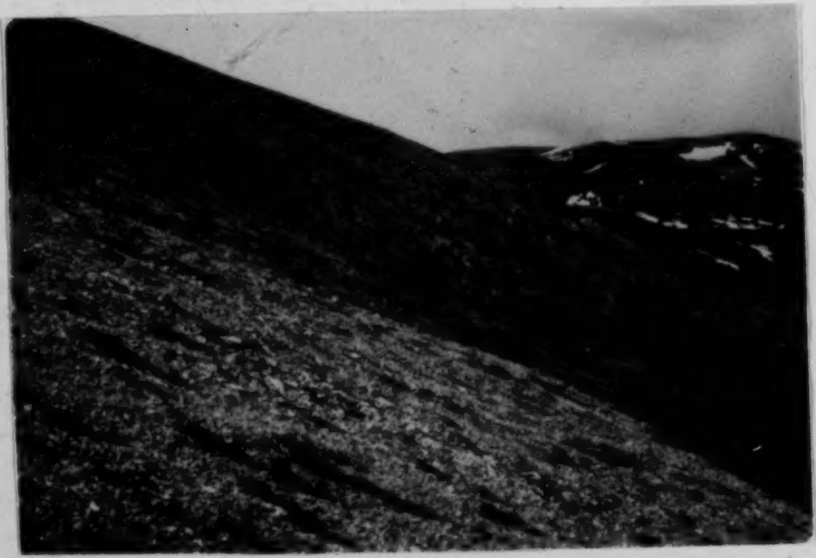


Plate 5. Junction of ct's 2 and 3 on a steep scree slope. The *Dryas integrifolia - Salix alaxensis* ct on limestone scree is in the foreground with its characteristic *Dryas* mats. The *Dryas integrifolia - Salix arctica* ct, with more evenly distributed plant cover, is beside it on the brown sandstone scree. (June 24, 1976)

mackenzii and *Oxytropis campestris* grow in the mat.

Despite the large amounts of *Arctostaphylos*, this stand has a high degree of similarity to the other stands of the *Dryas - Carex rupestris* ct. *Carex rupestris* is still a significant component having the third highest PV. *Androsace chamaejasme, Polygonum viviparum* and *Oxytropis campestris* are also important here, as in the other members of the ct.

The *Arctostaphylos* st is also found as solid patches in small depressions elsewhere on the slope.

2. *Dryas integrifolia - Salix alaxensis* (islands) community type (stand 7)

On a large, steep, NE-facing slope of limestone scree between R2 and R3, plant cover is almost completely restricted to mat 'islands' of *Dryas integrifolia*, 10 - 50 cm in diameter. Many mats are centered around gnarled and sprawling plants of *Salix alaxensis*, anchored firmly on the scree slope. Although some of these *Salix* plants have basal diameters of 5 cm or more, they rarely exceed 40 cm in height. The bare scree of small limestone rocks covers more area (77%) than the vegetation. Large boulders are rare.

Dryas integrifolia is the overwhelming dominant here. Although *Polygonum viviparum* and *Stellaria longipes* have low cover, they have a reasonably high quadrat frequency, particularly within *Dryas* mats. Other species which grow within the mats include *Pedicularis capitata, Silene acaulis, Oxytropis podocarpa, Saxifraga tricuspidata* and *Anemone parviflora*. Mosses and a few lichens occur in the *Dryas* islands as well.

Between the islands a few individual plants become established, notably *Saussurea densa, Pedicularis lanata, Saxifraga oppositifolia* and *Smelowskia calycina*. Some of these plants have long tenuous root systems stretching down through the rocks and far into the soil beneath. A few species appear to be restricted to these scree slopes, e.g. *Draba macounii*, *Cystopteris fragilis* and *Saxifraga caespitosa*.

The slope is unstable with some downslope movement of the surface material, and the vegetation mats are often broken and covered by the limestone rocks. Beneath the scree layer there is considerable soil, although the profile is still Regosolic. This soil is a silt loam to a silty clay loam with average moisture retention. It thus appears that substrate factors are much less of a factor in preventing continuous plant cover than is slope instability.

This ct is found, with lesser or greater amounts of plant cover, on a number of steep scree slopes at various altitudes and aspects.

3. *Dryas integrifolia* - *Salix arctica* community type (stand 8)

Although stands 7 and 8 are adjacent and situated on the same scree slope, their differences are reflections of a substrate change. Stand 8 is located in an area of sandstone scree as opposed to the limestone scree of stand 7. Despite the contrast in scree petrology, many of the soil characteristics, such as pH and texture, are similar.

Dryas integrifolia is still dominant but *Salix arctica* assumes much greater significance here than in the other Rock Tundra communities. *Astragalus alpinus* is the dominant legume and the third most important species. It is of interest that *Carex rupestris*, which had a low PV on the limestone scree, is completely absent from this stand. *Dryas octopetala* occurs here and is found in only one other Rock Tundra ct (stand 5), also on a sandstone substrate. Other species which are notably present are *Cerastium beeringianum*, *Androsace septentrionalis*, *Castilleja occidentalis* and *Erigeron lanatus*.

Although bare ground cover is slightly lower, in general the relative cover of vascular plants, mosses and lichens is about the same in this ct as in the *Dryas* islands ct on limestone scree. The number of species per quadrat (NSQ) and the total number of species is, however, slightly larger. This is the result of the restriction of plant cover to the *Dryas* islands in stand 7 as opposed to stand 8 where the individual plants are more evenly dispersed over the slope. This contrasting pattern makes the 2 areas visually distinct, despite the close similarity of their species structure (IS = 62%).

This ct is found on all sandstone scree slopes. These slopes are, however, fewer in number and smaller in area than the limestone slopes.

4. *Dryas integrifolia* - *Oxytropis podocarpa* community type (stand 18)

Large areas of the NE- and NW-facing slopes of R2 are covered by a relatively mesophytic *Dryas* - *Oxytropis podocarpa* community. On the gentler slopes the topography is characterized by terraces as high as 1 m. As the slope steepens and/or the altitude increases, the terraces decrease in height until they resemble rock stripes. Species composition of the terrace risers and stripes is similar with a high cover of both mosses and vascular plants. The terrace tops, on the other hand, are almost void of plant life. These areas are composed more of moist bare soil than rock. Where stripes are formed rather than terraces there is a greater percentage of rock.

Dryas integrifolia and *Oxytropis podocarpa* have the highest PV's in this community, but *Kobresia bellardii* is perhaps the most conspicuous

Plate 6. The *Dryas integrifolia - Oxytropis podocarpa* community (ct 4) on the N-facing slope of R2. The view is of the lee side of a wide, heavily vegetated stripe. The dominant *Dryas* is in bloom. The dark brown areas are moss, and the light brown graminoid which is particularly obvious in the background is *Kobresia bellardii*. (July 31, 1976)

component. This species forms large tufts along the edges of the terraces and stripes giving a more lush appearance than that exhibited by other Rock Tundra ct's. *Polygonum viviparum*, common in most Rock Tundra communities, has an even higher PV here. Legumes are also significant , but here the important species are *Hedysarum alpinum* and *Oxytropis campestris* as well as *Oxytropis podocarpa*. *Hedysarum mackenzii* is completely absent. Species of lesser importance include *Androsace chamaejasme, Carex rupestris, Pedicularis capitata, Salix nivalis, Smelowskia calycina* and *Saxifraga tricuspidata*. *Arnica louiseana* is found here and in only one other site on the mountain.

This ct has the highest species richness and the highest NSQ in the Rock Tundra Group. However, vascular plant cover averages only 45% due to the heavy concentration of plants in the terrace risers and stripes. Mosses achieve their highest cover value for this group in this ct, forming large mats beneath and amongst the vascular plants. Terricolous lichens are scattered throughout.

The soil pH, at 7.3, is comparable with that in the other Rock Tundra types. Soils are thin Orthic Regosols with a large percent coarse fraction.

Although this ct is found on only one ridge of Prospect, its cover there is extensive.

4a. *Kobresia bellardii* subtype (stand 21)

On one NW-facing slope of the *Dryas integrifolia - Oxytropis podocarpa* ct, *Kobresia bellardii* becomes even more prominent, obscuring many species of lower stature. Here *Kobresia* tufts form the basis of heavily vegetated, continuous and discontinuous, stripes perpendicular to slope contours. *Kobresia* is restricted to the outer, windward edge of the stripes. The rest of the vascular species are found in the lee of the dense sedge clumps, underlain by a thick moss layer. Only a few species of the ct are restricted to this st, i.e. *Gentiana propinqua, Astragalus vexilliflexus, Poa arctica, P. pattersonii* and *Draba cana.*

Although this stand is very similar in physical (soil) and vegetational characteristics to the type stand (IS = 77%), the increase in *Kobresia* cover and the subsequent effect on the organisation and visual appearance of the stand make it more suitable as a separate st.

4b. Sandstone outcrop subtype (stand 5)

Although the species composition and species structure of this stand are very similar to those of the other stands of the *Dryas* - - *Oxytropis podocarpa* ct, enough differences do occur to warrant a separate st distinction. This stand is located on an exposed, windswept sandstone outcrop on R4. Plants are widely separated, individual or in clumps, with no discernible patterning.

Dryas integrifolia is dominant followed by *Oxytropis podocarpa* as in the other stands in this ct, but both *Kobresia bellardii* and *Polygonum viviparum* are absent. The *Dryas* forms small mats with *Saxifraga tricuspidata* clumps within them. *Oxytropis podocarpa* is most commonly found growing singly. Grasses, especially *Calamagrostis purpurescens* also form clumps apart from the *Dryas* mats. As the slope increases down from the ridge the plant cover decreases, and the individual plants become even more scattered. Where resistant seams of rock run through the outcrop, unequal weathering has created small rock ridges, .25 - .5 m high. *Saxifraga tricuspidata* and *Telesonix* *jamesii* cover large areas of these ridge faces. *Astragalus alpinus, Carex rupestris* and *Erigeron compositus* are also significant in this community. Species found here with restricted distribution elsewhere on the mountain include *Senecio canus, Draba paysonii, Botrychium lunaria, Astragalus aboriginum, Eriogonum androsaceum* and *Telesonix jamesii.*

Despite the low mean cover of vascular plants, 28%, and a low NSQ of 3, the species richness of this stand is high at 44 and comparable to the other stands in the *Dryas - Oxytropis podocarpa* ct. Many species have low PV's and add little to the total cover but increase the species richness. Moss and lichen cover are low to negligable here.

Soils in this stand have the lowest pH of any in the Rock Tundra Group, 6.8, but they are still Orthic Humic Regosols.

This stand is unique and this community st is found only on this single outcrop on R4. Similar sites of sufficient size to sample do not seem to occur anywhere else on the mountain.

5. *Dryas integrifolia - Cassiope tetragona* community type (stand 10)

This ct occurs below the *Dryas - Carex rupestris* rock stripes on some gentle NW exposures. The microtopography includes quite pronounced terraces and very flat rock stripes of small stones, as this ct occupies the transition between these two periglacial features. There is less exposed rock surface here than in the *Dryas - Carex* ct above it.

On the risers of the larger terraces large clumps of *Cassiope tetragona* are mixed with *Dryas integrifolia* and *Arctostaphylos rubra.* Scattered throughout are larger *Salix* shrubs, 15 - 30 cm high, such as *S. arctica, S. alaxensis* and *S. vestita,*with occasional small krummholz

Abies lasiocarpa. Common herbs include *Polygonum viviparum, Oxytropis podocarpa, Tofieldia pusilla, Silene acaulis, Carex rupestris* and *Saxifraga oppositifolia,* most of which are common on the dry upper slopes. Floristically as well as physically this ct is situated between the moister *Dryas - Betula glandulosa* shrub community (ct 7) and the drier *Dryas - Carex rupestris* rock stripe community above, and is equally similar to both (Appendix II).

Total vascular plant and bryophyte cover are higher here than in the *Dryas - Carex* ct, but lower than those of the *Dryas - Betula* shrub type. Moss carpets are rare but mosses may be locally abundant. Where *Cassiope tetragona* dominates, *Hylocomium splendens* is often the understory. Terricolous lichens, especially fruticose forms, are scattered throughout. Sometimes *Dryas* and *Alectoria ochroleuca* form a narrow but distinct band between the *Cassiope*-dominated areas and the bare rock stripes.

Total vascular species richness for this community is intermediate between those of the rich *Dryas - Betula* community and the depauperate *Dryas - Carex* community. However, the NSQ more closely resembles that of the Shrub Stripe stands (Tables 7, 8).

Soil characteristics are also intermediate, but the coarse fraction and pH do fall within the range shown by the Rock Tundra Group.

This community type covers a small area but occurs on a number of ridges occupying the same ecological position with respect to aspect, slope and altitude. It consistently occurs below the *Dryas - Carex* community and usually above the *Dryas - Betula* community.

6. *Dryas integrifolia - Hedysarum mackenzii* community type (stand 17)

At the base of the large rock faces and scree slopes which lead to the peak of Prospect Mountain is a sheltered, gently sloping site occupied by the *Dryas - Hedysarum mackenzii* ct. Large calcareous rocks and piles of gravel, fallen from the rock face, occur in scattered patches. In spring small streams of meltwater from the upper slopes cut through the community in rocky channels. In times of rapid runoff gravel and rocks are deposited in the vegetation itself.

In spite of this rocky substrate, vascular plant cover is the highest for the Rock Tundra Group, due to an almost continuous mat of *Dryas integrifolia. Hedysarum mackenzii* ranks second in PV and is evenly scattered amongst the *Dryas*. Other legumes are rare or absent. Small sedges, primarily *Carex scirpoidea* and *C. rupestris*, form a thin layer above the *Dryas*. The only other quantitatively important species are *Polygonum viviparum* and *Androsace chamaejasme*. Vascular species richness is intermediate for the Rock Tundra Group (32), but of these, 25 species are rare and exist as widely separated individuals. Shrubs such as *Ledum groenlandicum, Salix vestita* and *Potentilla fruticosa* occur only in the few shallow depressions.

Bryophyte and lichen cover are low. Mosses occur only in small patches. The most common lichens are foliose and crustose, growing on the soil.

The soils are thin, Orthic Humic Regosols with a comparatively small percent coarse fraction.

This ct is found only in this one location on Prospect, between R3 and R4. In central areas the plant cover is high becoming lower towards the edges of the community and continues as clumps and individual plants up the adjacent scree slopes and rock slides. Due to the sheltered nature of this area, and its proximity to escape terrain, mountain sheep are often seen grazing here.

Shrub Tundra Group (Table 8)

A. Shrub Stripe Subgroup

7. *Dryas integrifolia* - *Betula glandulosa* community type (stands 9,11)

The *Dryas* - *Betula glandulosa* ct extends over a wide range of altitudes and slopes but is mostly restricted to NW exposures, where it can be very localized or cover an entire slope. The topography varies from flat rock stripes to terraces with risers up to 1 m high. Despite the terraced topography, there are only small patches of exposed soil and rock, and in some areas the rock stripes are completely vegetated.

As in other striped and terraced communities, *Dryas integrifolia* is the dominant vascular plant. *Betula glandulosa* is next in importance followed by *Arctostaphylos rubra*. *Salix arctica* and *S. nivalis* are present in small amounts adding to the shrubby nature of this community's physiognomy. Notable herbs are *Kobresia bellardii*, *Polygonum viviparum* and *Oxytropis podocarpa* — species common to all stripe communities. Stand 9 is located at the base of a slope and is watered by a nearby stream. Its more mesic environment is reflected by the presence of *Pyrola grandiflora*, *Senecio lugens*, *Tofieldia pusilla* and *Pedicularis flammea*, which are usually found in moist habitats. In stand 11 *Elymus innovatus*, *Poa rupicola*, *Potentilla fruticosa* and *Pedicularis*

Table 8. Selected site and community attributes of stands of the Shrub Tundra Group. See Table 6 (page 54) for names of community types.

	ct 7			ct 8	ct 9	ct 10	
	stand 9	stand 11	stand 19	stand 30	stand 26	stand 25	stand 16
Date	July 11	July 12	July 28	Aug. 13	Aug. 3	Aug. 5	July 26
Altitude (m)	1981	2057	2067	2055	1978	2027	2045
Slope (°)	12	24	34	32	10	26	2
Aspect	NW	NW	E	NE	NW	E	E
Soil type**	O.HR.	O.HR.	O.HR.	C.HR.	O.HR.	O.HR.	O.HR.
Surface pH	6.9	6.4	7.5	6.8	6.3	6.0	7.4
% coarse fraction	24	17	63	19	27	32	30
% available moisture (< 2 mm)	36	10	7	31	32	23	18
No. quadrats	30	30	30	15	30	30	30
No. vascular species	40	37	48	44	47	67	45
NSQ	7	8	7	13	10	8	6
$\bar{x}$ cover (%) -							
vascular species	70	55	79	80	72	86	76
mosses	69	58	20	9	50	7	3
lichens - saxicolous	0.2	0.4	0.3	1	0.2	0	0
terricolous	10	10	3	1	8	0.2	0
bare ground	11	4	9	5	2	4	17
PV vascular species -							
Dryas integrifolia	273	196	186	9.6	43	+	0.03
Betula glandulosa	130	62	102	-	52	-	-
Arctostaphylos rubra	47	55	2.2	-	48	+	-
Hedysarum alpinum	40	20	28	78	43	6.8	5.1
Kobresia bellardii	20	9.0	50	-	2.9	1.1	-
Salix nivalis	12	35	2.2	11	21	+	0.1
Polygonum viviparum	14	27	0.9	12	4.1	1.2	2.9
Solidago multiradiata	0.4	8.5	0.03	2.1	1.2	1.2	13
Oxytropis podocarpa	7.4	9.5	+	-	1.4	-	-
Pedicularis capitata	3.1	2.8	-	1.1	8.3	0.03	0.03
Potentilla diversifolia	0.5	1.2	0.1	2.8	0.3	0.7	1.2
Zygadenus elegans	+	0.9	0.4	0.2	0.3	0.03	+
*Androsace chamaejasme**	0.2	0.8	0.2	0.2	1.1	0.03	0.2
Arnica alpina	0.1	0.1	0.8	-	0.03	+	+
Stellaria longipes	0.1	0.03	+	-	1.0	0.5	-
Silene acaulis	0.3	-	+	0.1	0.1	+	0.03
Arctostaphylos uva-ursi	3.6	-	1.1	-	-	-	-
*Pyrola grandiflora**	2.0	-	1.1	-	-	-	-
Anemone parviflora	2.3	0.1	+	-	-	-	-
Pedicularis lanata	-	2.4	-	-	-	-	-
Aster alpinus	1.0	-	0.3	-	0.1	-	-
Potentilla nivea	0.1	0.6	0.1	-	-	-	-
Carex rupestris	0.03	0.1	-	-	-	-	-
Gentiana prostrata	+	0.1	+	-	+	+	-
Cerastium beeringianum	0.1	-	-	-	-	-	+
Festuca baffinensis	0.03	+	+	-	-	+	-
*Carex misandra**	0.03	-	-	-	-	-	-
Draba lonchocarpa	-	0.03	-	-	-	-	-
*Smelowskia calycina**	+	+	+	0.1	-	-	-
Anemone drummondii	+	0.03	-	0.1	-	-	-
Abies lasiocarpa	+	-	+	-	+	-	-
*Pedicularis flammea**	+	-	-	-	-	-	-
Festuca brachyphylla	-	+	-	-	-	-	-
Poa rupicola	-	+	-	-	-	-	-
Potentilla diversifolia var. *multisecta*	-	+	-	-	-	-	-
Juniperus communis	-	-	32	-	-	-	-
Potentilla fruticosa	-	0.4	30	-	-	-	-
Oxytropis campestris	0.1	2.2	9.7	-	-	-	0.03
Aster sibericus	-	-	7.6	-	-	-	1.0
Juniperus horizontalis	-	-	6.4	-	-	-	-
Epilobium angustifolium	-	-	6.4	-	-	3.0	-
Bromus pumpellianus	-	-	5.8	-	-	0.7	1.4
Saxifraga tricuspidata	-	0.6	3.2	-	-	-	-
Habenaria viridis	-	-	0.1	-	-	-	-
Calamagrostis purpurascens	-	-	+	-	+	-	-
Minuartia rubella	-	-	+	-	-	-	-

Table 8. (cont.)

	ct 7			ct 8	ct 9	ct 10	
	stand 9	stand 11	stand 19	stand 30	stand 26	stand 25	stand 16
Draba oligosperma	-	-	+	-	-	-	-
Astragalus aboriginum	-	-	+	-	-	-	-
Salix arctica	9.6	0.6	41	125	51	29	0.03
Equisetum scirpoides	0.03	0.1	-	26	7.5	2.1	+
Astragalus alpinus	-	+	-	19	0.7	+	-
Parnassia fimbriata	-	-	-	19	-	7.3	+
Arnica cordifolia	-	-	-	16	-	-	-
Astragalus vexilliflexus	-	-	2.5	16	5.1	0.1	11
Antennaria alpina	-	-	0.03	15	-	-	+
Castilleja occidentalis	-	-	-	14	2.5	+	+
Poa alpina	0.03	+	0.03	3.8	0.9	+	0.1
Erigeron humilis	-	-	-	2.1	+	+	+
Sibbaldia procumbens	-	-	-	1.1	-	-	0.4
Poa cusickii	-	-	-	0.5	-	-	-
Minuartia austromontana	0.03	-	-	0.5	-	-	-
Myosotis alpestris	-	0.03	-	0.5	-	+	+
Parnassia kotzebuei	-	-	-	0.4	0.3	-	-
Saxifraga lyallii	-	-	-	0.1	-	+	-
Botrychium lunaria	-	-	-	0.1	-	-	-
Agropyron latiglume	-	-	-	0.1	-	-	-
Selaginella densa	-	-	-	0.1	-	-	-
Androsace septentrionalis	-	-	-	+	-	+	-
Arabis drummondii	-	-	-	+	-	+	-
Cassiope tetragona	+	-	-	-	75	-	-
Salix vestita	-	-	-	-	46	+	-
Senecio lugens	-	-	-	1.7	19	+	-
Linnaea borealis	-	-	1.8	-	9.9	-	-
Tofieldia pusilla	0.4	-	-	+	2.2	-	-
Carex atrosquama	-	-	-	0.2	1.7	+	+
Gentianella propinqua	-	-	0.3	0.5	0.9	0.1	-
Salix reticulata[*]	-	-	-	-	+	-	-
Ledum groenlandicum	-	-	-	-	+	-	-
Salix barrattiana	-	-	-	-	52	546	560
Thalictrum occidentale	-	-	-	-	-	66	-
Trollius albiflorus	-	-	-	-	-	48	-
Valeriana sitchensis	-	-	-	-	-	47	-
Elymus innovatus	-	6.9	21	-	+	36	15
Artemisia norvegica	-	-	-	19	1.6	25	29
Mertensia paniculata	-	-	0.6	-	0.6	22	1.6
Erigeron peregrinus	-	-	-	6.9	-	6.2	21
Petasites frigidus	-	-	-	-	-	18	-
Aconitum delphinifolium	-	-	-	0.5	0.4	5.4	5.6
Senecio triangularis	-	-	-	-	-	4.8	-
Achillea millefoium	-	-	-	1.7	-	4.7	1.4
Arnica diversifolia	-	-	+	-	0.03	2.6	-
Delphinium glaucum	-	-	+	-	0.03	2.6	-
Fragaria virginiana	-	-	-	-	-	1.1	-
Veronica alpina	-	-	-	0.2	-	0.9	0.03
Draba borealis	-	-	-	-	+	0.4	-
Equisetum arvense	-	-	-	-	-	0.3	-
Streptopus amplexifolius	-	-	-	-	-	0.1	-
Ranunuculus eschscholtzii	-	-	-	-	-	0.1	-
Mitella nuda	-	-	-	-	-	0.1	-
Aquilegia flavescens	-	-	-	-	-	0.03	+
Gentianella amarella	-	-	-	-	-	0.03	-
Luzula parviflora	-	-	-	-	-	0.03	-
Agropyron smithii	-	-	-	-	-	+	-
Veratrum eschescholtzii	-	-	-	-	-	+	-
Draba aurea	-	-	-	-	-	+	-
Epilobium hornmanii	-	-	-	-	-	+	-
Castilleja miniata	-	-	-	-	-	+	-
Arnica alpina ssp. *attenuata*[*]	-	-	1.7	-	+	-	12
Carex scirpoidea	-	-	-	0.7	-	-	10
Equisetum variegatum	-	-	-	-	-	-	1.3
Pyrola asarifolia	-	-	-	-	-	-	0.6
Deschampsia caespitosa	-	-	-	-	-	-	+
Oxyria digyna	-	-	-	-	-	-	+
Saxifraga aizoides	-	-	-	-	-	-	+

[*] disjunct species

[**] Soil types: O.HR. (Orthic Humic Regosol), C.HR. (Cumulic Humic Regosol)

lanata indicate drier site conditions. In spite of these environmental and associated floristic differences, the two stands are very similar in species structure (IS = 74%).

Bryophyte cover is high with mosses forming a continuous carpet, ~~as deep~~ as 30 - 40 cm, under the *Betula*. *Hylocomium splendens* usually dominates these carpets. Lichens are less important but still noticeable in the community with foliose and fruticose lichens, particularly *Stereocaulon*, most common.

The soils are Orthic Humic Regosols with a pH of 6.4 - 6.9. The drier nature of stand 11 is demonstrated by its lower available moisture.

The largest stands of this ct occur near treeline on NW-facing slopes, in some places forming a band of shrub tundra between the subalpine forest and the upper alpine slopes.

7a. *Dryas* - shrub subtype (stand 19)

The steep E-facing slope of R1 is also dominated by *Dryas* and *Betula*, but other shrub species have an increased relative importance here. The combined PV's of *Salix arctica*, *Juniperus communis* and *Potentilla fruticosa* equal that of *Betula*. Other low shrubs present in lesser amounts include *Arctostaphylos uva-ursi*, *A. rubra*, *Juniperus horizontalis* and prostrate *Abies lasiocarpa*. The shrubs form a layer 30 - 45 cm high. Topographically this area is similar to others of the type, with small terraces blending into rock stripes. Plant cover is not restricted to the terrace risers, though, and in some places mixtures of shrubs form dense patches 1 - 9 m^2 in area.

There are other compositional differences besides the increase in shrubs. *Linnaea borealis*, which has a restricted distribution in the alpine zone on Prospect, is not only found here but forms large mats beneath the shrub thickets. *Habenaria viridis*, found in no other ct, is common here. Graminoids, particularly *Elymus innovatus*, *Bromus pumpellianus* and *Kobresia bellardii* assume greater significance in this st, overtopping the shrubs in many places. Legumes also have increased cover and richness in this stand.

Total vascular plant cover is higher than in the ct, but there is less bryophyte and lichen cover (Table 8). Moss still forms a thick carpet but it is more patchy here.

Although the soil is an Orthic Humic Regosol, it has a higher pH, a larger coarse fraction and lower available moisture than the soils of the type.

Despite its relatively high similarity to the other stands of this ct ($\bar{x}$ IS = 65%), there are enough significant differences in community physiognomy and species composition to justify its subtype designation. Although found in a single location, it covers an entire slope giving it a large total area.

B. Willow Scrub Subgroup

8. *Salix arctica* - *Hedysarum alpinum* community type (stand 30)

In a large, concave area in the center of R4 is a series of large solifluction lobes. This is a late snow release area and is usually damp although there is little surface water. The lobe-top plant cover varies from rock stripes and *Cassiope tetragona* communities to meadow vegetation. The lobe fronts are all similar, though, covered with the rich *Salix arctica - Hedysarum alpinum* ct. This community covers a large total area but its stands are quite small, i.e. the solifluction riser fronts. The ct drops out towards the bottoms of the risers where the *Dryas - Hedysarum alpinum* meadow ct (ct 14) takes over.

This community is clearly dominated by *Salix arctica*, but herbs such as *Hedysarum alpinum* give the ct much of its distinctive character. Less abundant herbs are *Astragalus vexilliflexus*, *A. alpinus*, *Arnica cordifolia*, *Artemisia norvegica*, *Parnassia fimbriata*, *Castilleja occidentalis* and *Erigeron peregrinus*. Smaller herbs, such as *Equisetum scirpoides*, *Antennaria alpina* and *Polygonum viviparum*, are scattered beneath and between the larger plants.

Although the NSQ and plant cover are high, the community does not appear lush. Individual plants are smaller than normal, rarely forming clumps. There are few mosses or lichens under the vascular plants.

The soil is a Cumulic Regosol due to downslope creep of the solifluction lobes. The percent coarse fraction is small and the soil is hard and firmly compacted. Towards the base of the lobe risers the percent coarse fraction increases.

This ct is confined to one area where it occurs on numerous lobes with different aspects and elevations.

9. *Salix* spp. - *Cassiope tetragona* community type (stand 26)

On some lower NW slopes, in the midst of the *Dryas - Betula* and *Dryas - Cassiope* stripes, there are deep snow accumulation hollows. Soon after meltout these hollows appear to be dominated by *Cassiope tetragona*. Later, as the associated deciduous shrubs leaf out, it becomes evident that the *Salix* species have the highest cover. Because of its substantial non-heath shrub cover, and similarity to the other Shrub Tundra communities, this ct is placed here rather than in the Heath Tundra Group.

Cassiope tetragona has the highest individual PV, but several low shrubs, 30 - 60 cm high, follow closely behind – *Arctostaphylos rubra*, *Betula glandulosa*, *Salix vestita*, *S. arctica* and *S. barrattiana*. The three *Salix* species combined have the greatest prominence, both visually and numerically, and are therefore used to name the community. *Salix reticulata* and *S. nivalis* are also present in small amounts. In these hollows, where *Cassiope tetragona* is a dominant species, *Dryas integrifolia* is present rather than *D. octopetala* as is found in all other *Cassiope* communities. Notable herbaceous species are *Hedysarum alpinum*, *Senecio lugens*, *Linnaea borealis* and *Pedicularis capitata*. Krummholz *Abies lasiocarpa* is found occasionally with *Parnassia kotzebuei* beneath. This *Parnassia*, as well as the *Ledum groenlandicum* found here, have very limited distributions in the study area.

Total vascular species richness and NSQ are average. Total vascular plant cover is high, as is bryophyte cover, which is highest beneath patches of *Cassiope*. Terricolous lichen cover is above average due to large clumps of *Stereocaulon* sp. and *Peltigera rufescens* and to the fine crustose lichens on the bare soil.

The soils are Orthic Humic Regosols but have the lower pH values (6.3) associated with heath-filled hollows (Table 9).

This ct is found on numerous W to NW slopes, at or slightly above treeline. Most hollows are small in size, rarely exceeding 100 m^2 in area, but the large number of these hollows give a significant total area for this ct.

Plate 7. The *Salix* spp. - *Cassiope tetragona* community (ct 9) in a shallow depression on the N-facing slope of R3. The deep green plant is *Cassiope tetragona*. The deciduous shrubs are *Salix* spp. which are only beginning to leaf-out at this point. White patches on the ground are clumps of *Stereocaulon* sp.. A small *Abies lasiocarpa* seedling is visible at right. (June 24, 1976)

Plate 8. The *Salix barrattiana* - *Trollius albiflorus* community (ct 10) on the lower slope of R2. The *Salix* is grow-ing in depressions .5 - 1 m deep, surrounded by herb-rich, grassy margins. (Aug. 3, 1976)

10. *Salix barrattiana* - *Trollius albiflorus* community type (stands 16,25)

Dense patches of *Salix barrattiana*, .5 - 1 m tall, grow at the bases of many slopes. They flourish in flat areas with a good source of water and in deep, moist hollows, which may be widely separated or contiguous. Due to the heavy shading by the *Salix*, the ground beneath, whether fine textured or gravel, is quite bare. The *Salix barrattiana* communities can be very rich in species, though, with many tall herbs growing in or around the *Salix* clumps. In particular the moist walls and grassy margins of the depressions hold a diverse assemblage of small herbs (Plate 8).

Salix barrattiana is dominant with one of the highest individual PV's found in any community. In the spring, before the willows leaf out, *Trollius albiflorus* blooms and seems to carpet the hollows. In gravelly sites (stand 16) *Trollius* is absent, but in general it is quite diagnostic for the ct. Later in the season other large herbs become significant, e.g. *Elymus innovatus*, *Mertensia paniculata*, *Senecio triangularis*, *Artemisia norvegica*, *Thalictrum occidentale*, *Valeriana sitchensis* and *Erigeron peregrinus*. On the damp walls of the hollows *Ranunculus eschscholtzii*, *Epilobium hornmanii*, *Parnassia fimbriata* and *Draba aurea* are most common. Many species occur in only this ct, including *Veratrum eschscholtzii*, *Streptopus amplexifolius*, *Mitella nuda* and *Draba aurea*. Additional species are unique to areas with a gravel substrate (stand 16) such as *Deschampsia caespitosa* and *Pyrola asarifolia*.

Total vascular plant cover is high, approaching 100% in some areas, largely due to the *Salix* bushes. There are a few mosses but virtually no lichens in the dark moist understory.

Soil conditions are quite variable in the different stands, although the soils are always Orthic Humic Regosols. In areas of rapid spring runoff, gravel is scattered over the surface and the soils are shallow. Deep, dark profiles are most common in the moist hollows. The pH range is 6.0 - 7.4, from the moist to dry sites respectively.

This ct is scattered along the lower slopes of all of the ridges as small pockets and large shrubby thickets.

Heath Tundra Group (Table 9)

11. *Cassiope tetragona - Dryas octopetala* community type (stands 13,14)

Depressions on N- and NE-facing slopes often contain heath communities. In these areas of greater snow accumulation and later snow release, the *Cassiope tetragona - Dryas octopetala* ct occupies the outer rims, i.e. the areas first released from snow. The *Phyllodoce glanduliflora - Cassiope mertensiana* ct occupies the deepest central parts of these hollows. As a result the *Cassiope tetragona - Dryas octopetala* ct is situated between the lush *Phyllodoce glanduliflora - Cassiope mertensiana* community and the surrounding dry Rock Tundra communities. Several of the species characteristic of the Rock Tundra communities, e.g. *Kobresia bellardii, Silene acaulis* and *Saxifraga oppositifolia*, are found in open areas of the community and thus it has a higher similarity to most of the Rock Tundra communities ($\bar{x}$ IS = 5.7%) than does the *Phyllodoce glanduliflora - Cassiope mertensiana* ct ($\bar{x}$ IS = 1.3%; see similarity matrix in Appendix II).

Cassiope tetragona forms dense tufts and is the undisputed

Table 9. Selected site and community attributes of stands of the Heath Tundra Group. See Table 6 (page 54) for names of community types.

	ct 11			ct 12	
	stand 13	stand 14	stand 23	stand 12	stand 15
Date	July 25	July 25	July 31	July 25	July 25
Altitude (m)	2054	2018	2091	2021	2030
Slope (°)	24	22	24	20	30
Aspect	E	NE	NE	E	NE
Soil type**	O.R.	M***	O.R.	M	O.MB.
Surface pH	7.1	M	6.8	M	5.7
% coarse fraction	3	M	48	M	5
% available moisture (< 2 mm)	36	M	25	M	31
No. quadrats	15	15	15	15	15
No. vascular species	40	37	36	43	39
NSQ	8	9	9	9	8
$\bar{x}$ cover (%) -					
vascular species	62	80	64	78	85
mosses	17	4	21	8	14
lichens - saxicolous	1	0.1	1	0.1	0
terricolous	6	5	12	0.4	0.4
bare ground	43	12	9	17	6
IV vascular species -					
Cassiope tetragona	267	334	260	+	+
Dryas octopetala	91	107	33	0.1	6.2
Carex scirpoides	56	4.6	-	13	0.2
Polygonum viviparum	12	5.3	8.7	9.9	2.9
Silene acaulis	+	18	+	2.8	-
Anemone parviflora	3.3	5.9	8.5	11	2.9
Artemisia norvegica	+	1.0	13	13	14
Pedicularis capitata	0.2	2.9	7.1	-	+
Kobresia bellardii	3.9	-	2.5	1.2	4.8
Carex atrosquama	+	2.9	+	0.2	3.5
Castilleja occidentalis	0.4	+	2.1	+	-
*Androsace chamaejasme**	1.7	0.2	0.5	+	0.7
Poa alpina	0.7	0.2	1.7	1.4	0.1
Potentilla diversifolia	0.1	0.7	0.2	0.2	0.6
Antennaria alpina	0.2	0.2	+	2.5	0.2
Erigeron humilis	0.1	+	0.2	0.4	0.1
Seleginella densa	1.7	6.1	-	9.0	5.3
Salix vestita	+	5.4	-	-	-
*Pyrola grandiflora**	4.4	-	-	-	-
Oxytropis podocarpa	-	1.7	0.4	-	-
Saxifraga aizoides	1.2	0.7	-	-	-
Saxifraga oppositifolia	0.4	0.7	-	0.1	-
Tofieldia pusilla	0.7	-	-	-	-
Carex rupestris	-	0.7	+	-	-
Hedysarum mackenzii	0.4	0.2	-	-	-
Carex nardina	+	0.4	-	-	-
*Antennaria monocephala**	0.1	-	-	-	-
Carex scirpiformis	0.1	-	-	-	-
Festuca baffinensis	+	-	+	-	-
Oxyria digyna	+	+	-	+	-
Abies lasiocarpa	+	-	-	+	-
Arnica alpina	-	+	-	-	-
Taraxacum lyratum	-	+	-	-	-
Picea engelmanii	+	+	-	-	-

Table 9. (cont.)

	ct 11			ct 12	
	stand 13	stand 14	stand 23	stand 12	stand 15
Salix nivalis	7.8	13	97	15	3.9
Dryas integrifolia	-	6.6	27	-	-
Solidago multiradiata	1.7	3.2	24	1.4	0.7
Astragalus alpinus	-	-	19	+	-
Hedysarum alpinum	-	-	4.6	+	1.7
Equisetum scirpoides	-	1.1	3.9	-	0.5
Elymus innovatus	-	-	1.1	-	-
Senecio lugens	-	-	0.7	-	-
Trisetum spicatum	+	-	0.1	-	-
Gentianella propinqua	-	-	0.1	-	-
Minuartia austromontana	-	-	0.1	+	-
Minuartia rubella	-	-	0.1	-	-
Arctostaphylos rubra	-	-	-	-	-
Myosotis alpestris	-	+	+	-	-
Stellaria longipes	-	-	+	+	+
Potentilla diversifolia var. *multisecta*	-	-	+	-	-
Phyllodoce glanduliflora	8.8	0.4	-	501	200
Cassiope mertensiana	0.4	-	-	204	466
Salix arctica	+	+	2.6	11	33
Arnica diversifolia	-	-	-	27	9.7
Parnassia fimbriata	0.2	0.4	-	16	0.1
Aquilegia flavescens	-	-	-	13	4.6
Erigeron peregrinus	0.1	0.2	+	9.7	8.8
Sibbaldia procumbens	-	0.5	-	6.9	1.1
Zygadenus elegans	+	+	-	+	3.5
Pedicularis bracteosa	-	-	-	2.5	0.4
Antennaria lanata	+	-	-	+	0.4
Saxifraga lyallii	-	-	-	0.4	0.2
Ranunculus eschscholtzii	-	-	-	0.1	0.2
Poa cusickii	-	-	-	0.1	-
Senecio triangularis	-	-	-	-	0.1
Veronica alpina	-	-	-	+	+
Carex physocarpa	-	-	-	-	+
Moneses uniflora	-	-	-	-	+
Phyllodoce intermedia	-	-	-	-	+

* disjunct species

** Soil type: O.R. (Orthic Regosol), O.MB. (Orthic Melanic Brunisol)

*** no data

dominant with *Dryas octopetala* usually next in importance. *Dryas integrifolia* is present in lesser amounts at the edge of the community where it grades into Rock Tundra. Other significant species in this ct are *Salix nivalis, S. arctica, Carex scirpoidea, Solidago multiradiata, Polygonum viviparum* and *Anemone parviflora*. *Selaginella densa* is common on patches of bare ground. Occasional individuals of *Abies lasiocarpa, Picea engelmanii* and *Salix vestita* occur in the heath-filled hollows; they form krummholz around many hollows as well. *Antennaria monocephala* and *Carex scirpiformis* are found in this community and nowhere else in the study area.

The relative amounts of plant cover and bare ground can vary considerably in this type. Large dry patches are more numerous towards the perimeter. The cover of mosses and lichens is generally low.

The soil type grades from Regosolic profiles at the xeric outer edges of the community to Brunisolic profiles characteristic of the mesic inner areas. Associated with this is a gradient of pH from 7.1 at the outer edges to 5.7 in areas of greater snow accumulation and higher plant cover.

11a. *Cassiope tetragona - Salix nivalis* subtype (stand 23)

On the E-facing slope of R2 a *Cassiope tetragona*-dominated community is found on flat, protected sites rather than in depressional areas. *Salix nivalis* ranks second and *Dryas octopetala* third in this st. *Solidago multiradiata, Artemisia norvegica, Pedicularis capitata, Salix arctica* and *Dryas integrifolia* all have greater importance here than in the other stands of the type. Species found here but not in the other *Cassiope tetragona* stands include *Astragalus alpinus, Elymus*

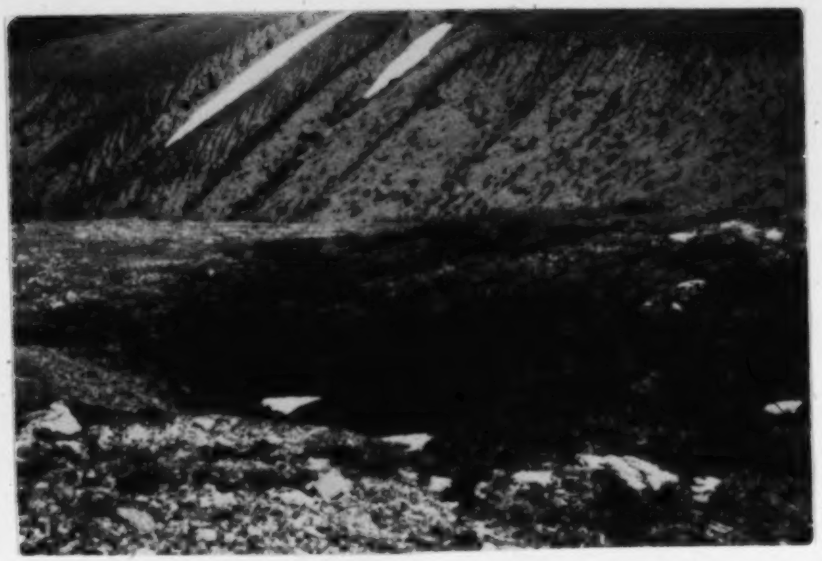


Plate 9. A well-developed heath hollow surrounded by Rock Tundra on the S-facing slope of R3. The dark brown *Cassiope tetragona* - *Dryas octopetala* community (ct 11) surrounds the dark green *Phyllodoce glanduliflora* - - *Cassiope mertensiana* community (ct 12) which is in the bottom of the depression and is released from snow later. *Abies lasiocarpa* krummholz are on the edge of the hollow. (June 24, 1976)

innovatus and *Hedysarum alpinum*. Many of the floristic differences of this st are due to its drier, more open nature as compared to the type. Consequently it has a higher similarity to the Rock Tundra communities which surround it (Appendix II).

Vascular plant cover is at the lower end of the range exhibited by this ct. Moss and terricolous lichen cover, however, are at the upper end.

The Regosolic soil profile and large coarse fraction reflect the flat dry slope habitat.

12. *Phyllodoce glanduliflora* - *Cassiope mertensiana* community type (stands 12,15)

In the deepest portions of the heath-filled depressions are relatively lush communities of *Phyllodoce glanduliflora* and *Cassiope mertensiana*. *Phyllodoce* is usually dominant but in some areas (e.g. stand 15) *Cassiope mertensiana* assumes dominance. Despite the change in dominants the species compositions of the two stands are quite similar. *Phyllodoce*- and *C. mertensiana*-dominated areas do not seem separated spatially or ecologically in any way, nor do they cover large areas of the landscape individually, therefore a single community type appears suitable.

Phyllodoce glanduliflora and *Cassiope mertensiana* are usually mixed together well. Combined in this thick matrix of heaths are lesser amounts of *Salix arctica* and *Artemisia norvegica*. Species with lower PV's but still significant include *Salix nivalis*, *Carex scirpoidea*, *Anemone parviflora* and *Polygonum viviparum*. Emerging above the heath mat in the deepest depressions are many large-leaf composites, e.g.

Arnica diversifolia, Senecio triangularis and *Erigeron peregrinus*. On the flatter sites *Aquilegia flavescens, Hedysarum alpinum* and *Castilleja occidentalis* assume greater importance. *Pedicularis bracteosa, Poa cusickii, Saxifraga lyallii, Ranunculus eschscholtzii* and *Senecio triangularis* are among those species found in the *Phyllodoce - Cassiope mertensiana* ct but not in the adjacent, drier *Cassiope tetragona* - - *Dryas octopetala* ct. *Moneses uniflora* is unique to this ct.

Vascular plant cover is relatively high with few bare areas. Bryophyte cover is low and lichens are virtually absent. Total vascular species richness and NSQ are both in the mid-range exhibited by all the ct's, and are remarkably consistant for all the Heath Tundra ct's: 36 - 43 and 8 - 9, respectively.

The soils of this community are well developed Melanic Brunisols. Where the slope is steep, turbic Melanic Brunisols can occur, caused by the downslope soil creep. Soil pH is the lowest of any measured on the mountain, 5.9. These soils also differ in having a small turf layer overlying the A horizon.

The *Phyllodoce glanduliflora - Cassiope mertensiana* ct is found in hollows of varying size, on E- and NE-facing slopes of most ridges, at a variety of altitudes.

Snowbed Tundra Group (Table 10)

13. *Salix arctica - Salix nivalis* community type (stand 31)

This stand is located in one of the larger snowbeds at the bottom of a steep SE-facing slope on R3, surrounded by rock stripes and Willow Scrub communities. Snow remains late into the growing season with final meltout in early August.

Table 10. Selected site and community attributes of the Snowbed Tundra Group.

	Salix arctica - S. nivalis ct stand 31
Date	Aug. 14
Altitude (m)	2050
Slope (°)	0
Aspect	-
Soil type**	O.HR.
Surface pH	7.7
% coarse fraction	35
% available moisture (< 2 mm)	17
No. quadrats	15
No. vascular species	30
NSQ	17
$\bar{x}$ cover (%) -	
vascular species	37
mosses	7
lichens - saxicolous	0.3
terricolous	1
bare ground	58
PV vascular species -	
Salix arctica	76
Salix nivalis	62
Anemone parviflora	28
Polygonum viviparum	18
Carex scirpoidea	10
Poa alpina	8.8
Equisetum variegatum	6.5
Saxifraga lyallii	4.5
Sibbaldia procumbens	1.7
Selaginella densa	1.2
Festuca baffinensis	1.1
Silene acaulis	0.7
Carex atrosquama	0.7
Potentilla diversifolia	0.4
Draba crassifolia	0.2
Erigeron humilis	0.2
Solidago multiradiata	0.1
Minuartia austromontana	0.1
Castilleja occidentalis	0.1
Tofieldia pusilla	+
Zygadenus elegans	+
Aquilegia flavescens	+
Saxifraga aizoides	+
Dryas integrifolia	+
Hedysarum alpinum	+
Hedysarum mackenzii	+
Oxytropis campestris	+
*Androsace chamaejasme**	+
Myosotis alpestris	+
Erigeron peregrinus	+

* disjunct species

** Soil type - O.HR. (Orthic Humic Regosol)

Plate 10. A *Salix arctica - Salix nivalis* snowbed (ct 13) on the S-facing slope of R3. The Snowbed Tundra community is surrounded by examples of the other 4 Tundra Groups. Behind it are well-developed *Dryas integrifolia* - - *Carex rupestris* Rock Tundra stripes. To the right of them, in a small depression, is a *Cassiope tetragona* Heath Tundra community (dark green). In the right foreground is a *Dryas* Meadow Tundra community (yellow-green), and to the left a *Salix barrattiana* Shrub Tundra community. (July 24, 1976)

Vascular plant cover is low (37%), with much bare ground, and the few plants present are low in stature. Even by the late sampling date, August 14, few species had flowered. *Salix arctica* and *S. nivalis* co-dominate forming a discontinuous mat. Scattered amongst the dwarf willows are *Anemone parviflora, Polygonum viviparum, Carex scirpoidea, Poa alpina, Equisetum variegatum* and *Saxifraga lyallii*. *Draba crassifolia* is restricted to this ct. Although there are 30 species in this ct, most have very low PV's contributing to this stand's depauperate appearance.

Mosses are small with low cover. Terricolous lichens are mostly crustose, growing directly on the bare soil surface.

Soil is poorly developed with a Regosolic profile and a high pH of 7.7. Large rocks are spread over the surface.

Snowbeds are found in sheltered areas on a number of slopes, but they are never large, rarely exceeding dimensions of 15 m X 15 m. The snowbed community varies considerably but this stand is representative.

Meadow Tundra Group (Table 11)

A. *Dryas* Meadow Subgroup

14. *Dryas integrifolia - Hedysarum alpinum* community type (stands 6,22,24, 29)

This variable ct occurs most commonly on gentle to moderate N-facing slopes, though occasionally stands are found with southern exposures. The concept of a basic plant assemblage for the type to which varying numbers of vascular plants are added is particularly well expressed in this ct. Total vascular species richness ranges from 31

Table 11. Selected site and community attributes of stands of the Meadow Tundra Group. See Table 6 (page 54) for names of community types.

	ct 14					ct 15	ct 16
	stand 29	stand 22	stand 6	stand 24	stand 20	stand 27	stand 28
Date	Aug. 13	July 31	July 9	Aug. 2	July 28	Aug. 10	Aug. 10
Altitude (m)	2050	2104	2067	2048	2030	2024	2027
Slope (°)	14	26	8	22	12	14	22
Aspect	NE	NE	SE	NW	NW	SE	E
Soil type**	O.HR.	O.HR.	O.R.	O.HR.	O.R.	O.HR.	O.HR.
Surface pH	7.0	7.1	7.5	7.3	7.1	5.8	5.6
% coarse fraction	21	28	48	53	58	38	33
% available moisture (< 2 mm)	25	21	15	19	48	6	7
No. quadrats	30	30	30	30	30	30	15
No. vascular species	41	71	31	34	35	56	35
NSQ	9	8	7	6	8	9	9
x̄ cover (%) -							
vascular species	74	51	55	75	50	83	88
mosses	53	26	4	38	85	8	3
lichens - saxicolous	0	1	1	0.1	0.1	8	0
terricolous	3	4	4	19	4	0	0
bare ground	0.4	26	39	4	0.3	3	0.1
PV vascular species -							
Dryas integrifolia	189	210	349	511	202	17	-
Hedysarum alpinum	79	76	74	116	53	50	0.4
Kobresia bellardii	73	18	25	16	31	2.5	-
Polygonum viviparum	29	19	3.4	27	38	0.3	-
Salix arctica	47	32	+	6.5	13	3.7	-
Stellaria longipes	26	2.0	-	+	1.6	3.7	0.1
Bromus pumpellianus	17	5.6	+	-	-	0.1	1.7
Oxytropis campestris	2.8	0.1	18	-	-	7.6	-
Poa alpina	5.2	4.3	0.6	0.1	3.4	0.03	0.1
Arnica alpina	+	2.3	3.1	+	1.4	+	+
*Androsace chamaejasme**	0.2	1.9	3.0	0.03	0.6	0.2	0.4
*Smelowskia calycina**	+	0.03	3.2	-	2.1	-	+
Gentianella propinqua	0.3	0.7	-	-	0.03	0.3	-
Poa arctica	0.1	0.03	-	0.1	0.5	0.3	+
Potentilla nivea	+	0.3	-	+	0.4	+	-
Trisetum spicatum	0.6	+	-	0.03	+	0.03	-
Pedicularis capitata	2.5	4.1	+	7.1	0.7	-	-
Saxifraga tricuspidata	-	2.8	1.7	-	+	-	-
Senecio lugens	15	+	-	-	3.0	-	-
Silene acaulis	0.1	+	-	2.4	0.4	-	-
Gentiana prostrata	0.03	0.2	-	0.03	0.03	-	-
Delphinium glaucum	-	1.4	-	-	0.1	-	-
Potentilla diversifolia var. *multisecta*	-	0.1	-	-	+	-	-
*Pedicularis flammea**	-	+	-	-	0.1	-	-
Saxifraga caespitosa	-	+	-	-	+	-	-
Salix nivalis	2.7	3.1	-	49	-	+	-
Oxytropis podocarpa	-	35	4.3	4.3	-	-	-
Calamagrostis purpurascens	0.03	-	17	-	-	-	-
Zygadenus elegans	3.7	+	2.4	-	-	0.6	-
*Salix reticulata**	-	3.6	-	-	-	-	-
Anemone parviflora	0.8	0.4	-	0.8	-	-	-
Pedicularis lanata	-	0.1	-	1.9	-	-	-
Carex rupestris	-	+	0.2	0.03	-	-	-
Betula glandulosa	-	-	2.2	-	-	+	-
*Carex misandra**	-	-	-	1.5	-	-	-
Antennaria alpina	+	-	1.4	-	-	-	-
Arctostaphylos rubra	1.1	+	-	+	-	-	-
Erigeron grandiflorus	1.1	+	-	-	-	-	-
Carex scirpoidea	0.7	-	-	-	-	-	-
Carex atrosquama	0.5	-	-	-	-	+	-
Erigeron compositus	-	+	0.4	-	-	-	-
Aster sibericus	-	0.4	-	-	-	0.03	-
Hedysarum mackenzii	-	-	0.4	-	-	-	-
Festuca baffinensis	-	0.2	-	-	-	-	-
Anemone drummondii	-	+	0.1	-	-	+	-
Astragalus vexilliflexus	-	0.1	-	-	-	-	-
Euphrasia disjuncta	0.1	-	-	-	-	-	-

Table 11. (cont.)

	ct 14					ct 15	ct 16
	stand 29	stand 22	stand 6	stand 24	stand 20	stand 27	stand 28
Minuartia rubella	-	0.03	-	-	-	-	-
Agropyron latiglume	-	0.03	-	-	-	+	-
Senecio canus	-	-	0.03	-	-	-	-
Saussurea densa	-	-	-	0.03	-	-	-
Saxifraga oppositifolia	-	-	-	0.03	-	-	-
Minuartia austromontana	+	+	+	-	-	-	-
Draba porsildii	-	+	-	+	-	-	-
Poa cusickii	+	-	-	-	-	-	-
Picea engelmanii	-	+	-	-	-	-	-
Salix vestita	-	+	-	-	-	-	-
Minuartia sajanensis	-	+	-	-	-	-	-
Draba albertina	-	+	-	-	-	-	-
Draba incerta	-	+	-	-	-	-	-
Dryas octopetala	-	+	-	-	-	+	-
Potentilla uniflora	-	+	-	-	-	-	-
Cassiope tetragona	-	+	-	-	-	-	-
Androsace septentrionalis	-	+	-	-	-	-	-
Castilleja occidentalis	-	+	-	-	-	-	-
*Erigeron radicatus**	-	-	+	-	-	-	-
Draba cana	-	-	-	+	-	-	-
*Campanula uniflora**	-	-	-	+	-	-	-
*Salix alaxensis**	-	-	-	-	95	-	-
*Oxytropis jordalii**	-	-	-	8.3	25	-	-
Aconitum delphinifolium	2.8	+	-	+	7.8	2.2	0.4
Aster alpinus	-	0.3	0.03	-	1.2	+	-
Festuca brachyphylla	+	+	+	+	0.4	-	-
Saxifraga cernua	-	-	-	-	0.03	-	-
Cerastium beeringianum	-	-	-	-	+	-	-
Draba borealis	-	-	-	-	+	-	-
Elymus innovatus	-	5.0	+	-	16	215	22
Mertensia paniculata	-	+	-	-	-	79	13
Fragaria virginiana	-	-	-	-	-	48	3.2
Astragalus alpinus	5.5	8.3	-	-	+	27	32
Equisetum scirpoides	-	+	-	-	-	14	0.4
Equisetum arvense	-	+	-	-	-	2.1	3.9
Oxyria digyna	-	-	-	-	-	+	+
Arabis drummondii	-	+	-	-	-	+	+
Juniperus horizontalis	-	-	-	-	-	55	-
Epilobium angustifolium	-	-	-	-	-	31	-
Solidago multiradiata	7.3	1.6	2.1	+	+	18	-
Potentilla gracilis	-	-	-	-	-	1.2	-
Gentianella amarella	-	-	-	-	-	0.6	-
Botrychium lunaria	-	-	-	-	-	+	-
Juniperus communis	-	-	-	-	-	+	-
Carex festivella	-	-	-	-	-	+	-
Arctostaphylos uva-ursi	-	-	-	-	-	+	-
Anemone multifida	-	-	-	-	-	+	-
Artemisia norvegica	10	+	-	-	-	3.5	643
Achillea millefolium	0.03	+	-	-	-	7.3	26
Epilobium latifolium	-	+	-	+	-	+	6.2
Potentilla diversifolia	1.0	0.1	0.03	-	0.4	3.9	6.1
Myosotis alpestris	+	0.1	+	+	0.6	0.6	4.7
Arnica cordifolia	-	-	-	-	-	+	4.8
Phleum alpinum	-	-	-	-	-	+	3.8
Taraxacum ceratophorum	-	-	-	-	-	+	1.7
Carex phaeocephala	-	-	-	-	-	+	0.2
Aquilegia flavescens	-	-	-	-	-	-	156
Castilleja miniata	-	-	-	-	-	-	12
*Arnica alpina ssp. attenuata**	-	-	-	-	-	-	9.1
Erigeron peregrinus	-	-	-	-	-	-	8.7
Heracleum lanatum	-	-	-	-	-	-	5.4
Arnica diversifolia	-	-	-	-	-	-	1.4
Poa pratensis	-	-	-	-	-	-	1.3
Ranunculus eschscholtzii	-	-	-	-	-	-	0.5
Sibbaldia procumbens	-	-	-	-	-	-	0.2

*disjunct species

** Soil types: O.HR. (Orthic Humic Regosol), O.R. (Orthic Regosol) to 71, with the species-rich stands generally in moister areas with a good source of water all season.

Dryas integrifolia and *Hedysarum alpinum* always rank first and second in PV. Other species found consistently are *Kobresia bellardii*, *Polygonum viviparum* and *Salix arctica*. *S. nivalis* and *Oxytropis podocarpa* are common in many stands. The drier stands (6 and 24) have some characteristic species of the Rock Tundra Group, e.g. *Erigeron radicatus*, *Senecio canus*, *Saussurea densa*, *Saxifraga oppositifolia*, *Calamagrostis purpurescens* and *Carex misandra*. The more mesic stands (29 and 22) have *Achillea millefolium*, *Artemisia norvegica*, *Senecio lugens*, *Aquilegia flavescens* and *Mertensia paniculata*, all species of moister habitats.

Plant cover is almost complete due to a continuous *Dryas* mat, but some of the drier stands have patches of bare ground and rock. In the more mesic sites bryophytes may form large mats with *Dryas*. Lichen cover is generally low.

Soils are all Orthic or Orthic Humic Regosols with alkaline pH values. The coarse fraction ranges from 21 - 53%, from mesic to xero-mesic sites. Areas with high plant cover often have a turf layer overlying the A horizon.

This ct covers large areas on equivalent topographic positions on R2 and R4, and as smaller stands in flat areas. The total extent of this ct in the study area is second only to that of the *Dryas integrifolia* - *Carex rupestris* ct.

14a. *Salix alaxensis* subtype (stand 20)

On NW-facing slopes the *Dryas-Hedysarum alpinum* ct blends into its st, with *Salix alaxensis* shrubs superimposed on the *Dryas* meadow physiognomy. This st occurs on moderate slopes where subsurface drainage is concentrated. A thick layer of moss ($\bar{x}$ cover = 85%) underlies the entire st.

The sprawling *Salix alaxensis* bushes are about 40 cm high and randomly dispersed on the *Dryas* and moss matrix. *Oxytropis jordalii* is common around the bases of the *Salix* bushes; it is found only here and in the adjacent stands of the ct. In addition to *Salix alaxensis*, *Saxifraga cernua*, *Draba borealis* and *Cerastium beeringianum* are found only in this st and not in the other stands of the type.

The soil is thin and rocky under the thick moss layer, but has the sufficient moisture supply necessary for this mesophytic community.

B. Herb Meadow Subgroup

15. *Elymus innovatus - Mertensia paniculata* community type (stand 27)

On the SE side of R4 is a lush, grassy meadow, bounded on 3 sides by stable scree slopes. Directly above the meadow is a snow cornice which melts slowly through most of the growing season, insuring a constant supply of water. The meadow itself is very hummocky, with *Juniperus horizontalis*, *Salix arctica*, and many herbs in the depressions around the hummocks. As the community continues downslope the amount of *Salix* in the depressions increases. At still lower altitudes this stand grades into krummholz islands of the subalpine zone.

Elymus innovatus is the dominant species followed by *Mertensia*

Plate 11. The *Salix alaxensis* st of the *Dryas integrifolia* - - *Hedysarum alpinum* meadow community (ct 14) on a flat bench of R2. Both *Dryas integrifolia* (white) and *Hedysarum alpinum* (pink) are in bloom around the sprawling *Salix alaxensis* bushes. (July 24, 1976)

Plate 12. The colourful, herb-rich *Artemisia norvegica - Aquilegia flavescens* community (ct 16) in a drainage channel on R4. It is bounded on both sides by the grassy *Elymus innovatus - Mertensia paniculata* community (ct 15). Above both communities is the snowbank which supplies them with water for most of the summer. (July 24, 1976)

paniculata. Less important are *Hedysarum alpinum, Potentilla gracilis, Epilobium angustifolium, Achillea millefolium, Fragaria virginiana* and *Solidago multiradiata.* These tall herbs give a characteristically lush appearance to the community. In areas lacking taller plants *Dryas integrifolia* and *Equisetum scirpoides* form the ground cover. *Carex festivella* is the only species exclusive to this ct.

The total number of vascular species and NSQ are both high, indicating relative richness at both levels.

There are few mosses or lichens, but in moist areas around the hummocks *Peltigera pulverulenta* can be found.

The soil is an Orthic Humic Regosol with a large percent coarse fraction and the second lowest pH after the *Phyllodoce* ct.

This grass-dominated community is utilized by a number of animals, especially Hoary Marmots which have burrows along its margins. Insect life is also abundant with numerous ants and grasshoppers.

16. *Artemisia norvegica - Aquilegia flavescens* community type (stand 28)

Close to the melting edge of the late snowbank above the previous ct, and in the damp drainage channels running from it, is another lush Herb Meadow community. Above it, in areas where snow lies very late into the summer, there is little or no plant life. This community, therefore, is bounded on 2 of 4 sides by the *Elymus - Mertensia* ct, on 1 side by the melting snowbank, and on the other by a hard scree slope with sparsely scattered *Myosotis alpestris, Phacelia sericea* and *Arnica cordifolia* plants. Although adjacent to the *Elymus - Mertensia* ct, its species structure is very different (IS = 11%).

The ct is overwhelmingly dominated by *Artemisia norvegica* (PV = 643). More obvious collectively, though, are the many showy herbs such as *Aquilegia flavescens, Arnica cordifolia, Mertensia paniculata, Erigeron peregrinus, Potentilla diversifolia* and *Castilleja miniata*. The giant herb *Heracleum lanatum* is found in the dampest sites and towers above the other plants. Shrubs are almost completely absent. Below the tall species are low herbs, e.g. *Astragalus alpinus* and *Myosotis alpestris*. Despite the luxuriant and colourful appearance of this community it contains only 35 vascular species.

Vascular plant cover is high (88%) with virtually no bare ground visible. There are a few mosses but no lichens.

The soil is very similar to that of the adjacent *Elymus - Mertensia* ct. There is, however, a higher clay content (Table 14, page 111).

This community is restricted in habitat to very moist areas with a constant water supply. Because of these special requirements its total area is small.

Other Communities

Two plant assemblages were described but not sampled quantitatively. Examples of these two types were found in restricted areas, and although habitat conditions seemed relatively constant, species composition varied greatly.

Drainage Channels

Narrow V-shaped channels which collect snow and/or carry runoff water are found on all ridges. They vary in slope angle, aspect and total length. Their species composition varies with the steepness, date of snow release, amount of exposed rock, and the dominant surrounding vegetation. The communities are mainly herbaceous but some contain low *Salix* spp..

Artemisia norvegica, Salix arctica, Aconitum delphinifolium, Epilobium latifolium, Myosotis alpestris and *Parnassia fimbriata* are the most constant species, and *E. latifolium* achieves its highest cover in these areas.

Some channels are filled with swiftly flowing water in spring and after heavy rains, restricting the plant cover to the mesic channel walls. *Artemisia norvegica* dominates, and *Oxyria digyna, Saxifraga lyallii, Senecio lugens* and *Claytonia lanceolata* are common on these walls.

Rock Faces

On steep, exposed rock faces, both of limestone and sandstone, the plant cover is restricted to isolated individuals established in cracks and on ledges. Although most of the Rock Tundra species are found here, cushion plants, e.g. *Potentilla uniflora, Eriogonum androsaceum* and *Saxifraga tricuspidata*, and caespitose grasses, e.g. *Festuca baffinensis* and *Trisetum spicatum*, are particularly successful *Cystopteris fragilis, Saxifraga cernua* and *S. caespitosa* are almost restricted to these outcrops. *Telesonix jamesii* is notable at the base of large limestone boulders.

Community cover is always low, but species composition and richness vary considerably. A single area may have more than 20 species with none being discernably dominant, or a single species may prevail. On the sheer E-facing cliffs of R4, *Potentilla uniflora* is virtually the sole colonizer.

On rock faces at higher altitudes the plants are even more scattered, but this is the main habitat for *Papaver kluanensis*. *Draba macounii* and *D. lonchocarpa* continue upward almost to the line of permanent snow.

Rock faces and outcrops cover small areas on the 4 main ridges but dominate the topography above 2285 m ASL.

Transect Studies

Transect #1

Transect #1 runs in a N - S direction for 90 m over patterned ground, both rock stripes and terraces, on the NW face of R3 (Plate 13). The transect covers a change in altitude of 25 m, from 2034 m to 2059 m ASL. Three main ct's and their intermediates are traversed: a broad belt of *Dryas integrifolia* - *Betula glandulosa* shrub stripes, a small patch of *Dryas integrifolia* - *Cassiope tetragona* stripes, and *Dryas integrifolia* - *Carex rupestris* stripes. The 3 stripe ct's interfinger, alternate and overlap. The microtopography is characterized by terraces oriented along the slope contours at the lower end of the transect, and by rock stripes perpendicular to the contours at the upper end. The *Dryas* - *Betula* ct continues downslope from the origin of the transect for a considerable distance, and the *Dryas* - *Carex* ct does the same upslope.

Cover values for selected species on the transect are contained in Table 12; the remaining species are in Appendix IV. *Dryas integrifolia* dominates all portions of the transect. Other ubiquists with lesser cover include *Carex rupestris*, *Androsace chamaejasme*,

Table 12. Quantitative values of selected site and community attributes along Transect #1. Additional species are presented in Appendix IV.

	Transect Segment*														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
$\bar{x}$ slope (^{o})	23	20	14	24	13	18	22	17	11	24	25	31	24	24	15
altitude (m)	2034				2047					2052				2059	
no. vascular spp.	13	15	14	12	13	17	16	12	16	15	13	10	9	11	11
$\bar{x}$ cover (%):															
vascular plants	65	54	69	69	82	44	76	40	69	57	48	63	59	63	56
mosses	35	25	25	26	21	28	9	2	3	32	3	2	11	3	-
lichens - saxicolous	-	+	+	+	-	+	+	+	-	+	+	1	1	-	+
terricolous	4	15	13	8	11	13	15	10	11	13	15	20	16	18	15
rock	1	22	16	8	+	5	1	34	5	10	21	6	32	8	28
soil	1	6	3	6	3	8	2	11	3	1	8	11	1	3	6
Dryas integrifolia	44	45	35	48	63	24	48	48	48	10	35	59	52	52	56
Carex rupestris	-	+	+	+	+	+	+	1	1	+	+	+	-	+	1
Kobresia bellardii	-	1	1	+	1	+	+	1	1	+	+	+	-	+	1
Androsace chamaejasme	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+
Salix nivalis	1	+	-	1	1	1	2	1	1	1	1	+	1	1	+
Pedicularis capitata	1	+	1	+	+	+	-	-	+	-	+	-	+	+	-
Polygonum viviparum	+	+	+	+	1	+	1	+	1	+	+	+	+	+	+
Salix vestita	22	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Equisetum scirpoides	+	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Picea engelmanii	-	-	16	-	-	-	-	-	-	-	-	-	-	-	-
Betula glandulosa	3	5	3	18	5	15	-	-	-	-	-	-	-	-	-
Anemone parviflora	+	+	-	-	-	+	+	-	+	-	-	-	-	-	-
Pyrola grandiflora	+	+	1	1	+	-	-	3	-	-	+	-	-	-	-
Cassiope tetragona	23	-	3	-	-	-	1	-	-	12	-	-	-	-	-
Hedysarum alpinum	6	6	5	10	13	6	13	3	-	5	-	-	-	-	1
Arctostaphylos rubra	-	5	25	-	-	3	3	-	3	-	8	-	-	-	-
Saxifraga oppositifolia	-	-	+	+	-	1	1	+	+	+	1	+	-	1	+
Oxytropis podocarpa	-	-	3	+	3	3	4	+	6	+	1	4	3	3	3
Poa alpina	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-
Aster sibericus	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-
Salix arctica	-	-	-	-	+	-	-	-	-	10	-	-	3	-	-
Dryas octopetala	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
Hedysarum mackenzii	-	-	-	-	-	-	-	1	8	+	3	3	3	16	+

* 4 consecutive quadrats (nos. 1-4, 5-8, etc.)

Salix nivalis and *Polygonum viviparum*. *Saxifraga oppositifolia* and *Oxytropis podocarpa*, though absent from the dense *Betula* stripes, are common over the rest of the transect.

The *Dryas* - *Betula* ct (transect segments 1 - 6, Table 12) is characterized by *Salix vestita*, *Equisetum scirpoides*, *Hedysarum alpinum*, *Pyrola grandiflora* and *Arctostaphylos rubra*. *Cassiope tetragona* may be locally abundant. Transect segment 3 traversed a *Picea engelmanii* krummholz, hence the high cover for that species there and its absence elsewhere. Moss cover is particularly high in this transect area.

Transect segments 7 - 9 are transitional between the *Dryas* - - *Betula* and the *Dryas* - *Cassiope* ct's, with *Cassiope* found in association with *Salix arctica*, *Hedysarum alpinum* and *Dryas octopetala*.

The *Dryas* - *Carex* stripes (segments 12 - 15) are located in stand 1 (Table 7, page 61), therefore *Oxytropis podocarpa* cover is high. Species richness is lower than in the rest of the transect, shrubs are few, and the species composition is primarily ubiquists, i.e. there are no diagnostic species. There is, however, a small increase in the cover of terricolous lichens.

The legumes show a distinctive distribution pattern. The ranges of *Hedysarum alpinum* and *H. mackenzii* are almost mutually exclusive. *H. alpinum* is found only on the lower slopes and gives way to *H. mackenzii* on the upper. They overlap only slightly in the *Dryas* - - *Cassiope* stripes. *Oxytropis podocarpa* is common on most of the slope, but *O. campestris*, restricted to S-facing slopes, is absent.

The amounts of bare rock and soil vary strongly from one segment to another, indicative of the patterned ground. The most heavily

Plate 13. Transect #1 on the N-facing slope of R3. The transect starts in *Dryas integrifolia - Betula glandulosa* terraces (bright green stripes), travels through *Dryas integrifolia - Cassiope tetragona* stripes (dark brown stripes) and terminates in *Dryas integrifolia - Carex rupestris* stripes (light brown stripes) on the upper slopes. Patches of the *Salix* spp. - *Cassiope tetragona* community are in the foreground. (July 24, 1976)

vegetated sites are at the lower end of the transect. Both species richness and total plant cover decrease upward along the transect.

The changes in species composition and structure observed on this transect are mainly a reflection of the change in topographic position. All areas are released from snow simultaneously, and slope angle does not increase appreciably with altitude.

Transect #2

Transect #2 runs 49 m in an E - W direction in a large central depression on R4. Originating at 2080 m, it rises less than 2 m over its entire length from a flat *Dryas* meadow, through heath communities on the sloping edge, and terminating in the rock tundra surrounding the depression (Plate 14). This transect covers a snowmelt gradient, but it is not a continuous one from center to edge. The rock tundra is released first, meadow areas are second and the sheltered heath slopes are last.

Only a few ubiquists occur along the entire transect, notably *Salix nivalis, Polygonum viviparum, Anemone parviflora* and *Pedicularis capitata* (Table 13). *Dryas integrifolia* and *Hedysarum alpinum* have a bimodal distribution, being common in the meadow segment and the edge of the *Cassiope tetragona* community where it grades into the rock tundra. They are absent from the *Phyllodoce*- and most of the *Cassiope tetragona*-dominated quadrats. *Salix arctica* is widespread across both heath communities and parts of the meadow.

The *Dryas* meadow portion (transect segments 1 - 4, Table 13) is dominated by *Dryas integrifolia* and *Hedysarum alpinum* with the herb meadow components, *Astragalus alpinus, Kobresia bellardii* and

Table 13. Quantitative values of selected site and community attributes along Transect #2. Additional species are presented in Appendix IV.

	Transect Segments*																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20**
x̄ slope (°)	7	1	2	6	2	7	16	20	18	18	26	14	12	15	12	13	5	15	8	6
no. vascular species	15	20	20	23	27	25	12	14	19	19	18	20	21	21	17	18	10	13	12	6
x̄ cover (%):																				
vascular plants	68	73	73	69	88	88	88	88	88	88	83	83	78	78	78	64	83	68	20	49
mosses	73	18	4	5	1	3	-	2	14	7	15	31	12	1	4	5	4	1	1	7
lichens - saxicolous	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+	+	2	+
terricolous	11	22	3	3	1	1	-	-	1	3	3	2	4	7	6	13	6	3	3	5
rock	-	-	6	+	-	-	-	+	+	-	-	+	-	+	-	-	+	30	47	17
soil	-	1	5	21	+	1	1	1	+	5	5	7	16	9	7	14	5	1	25	19
Anemone parviflora	+	+	+	2	1	1	+	+	+	+	+	1	+	-	1	1	+	+	-	-
Polygonum viviparum	4	2	5	4	4	3	-	+	2	2	1	1	+	2	1	1	1	+	+	1
Salix nivalis	1	2	8	26	31	1	-	+	2	5	18	2	3	5	3	7	3	2	1	1
Equisetum scirpoides	-	-	+	1	+	+	+	1	1	2	3	1	+	1	2	+	+	1	+	-
Pedicularis capitata	+	1	+	1	+	1	-	+	1	1	+	1	1	1	1	+	1	+	-	+
Bromus pumpellianus	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Zygadenus elegans	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gentiana prostrata	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Astragalus alpinus	+	4	5	3	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Hedysarum alpinum	6	9	7	5	5	-	-	-	-	-	-	1	-	1	1	8	5	-	-	-
Kobresia bellardii	7	2	1	1	1	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salix arctica	1	-	3	5	19	23	9	4	2	3	2	1	2	2	-	+	-	-	+	-
Oxytropis campestris	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Silene acaulis	-	-	+	1	+	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Castilleja occidentalis	-	-	-	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Artemisia norvegica	-	-	-	1	3	+	-	1	1	3	1	1	+	+	-	-	-	-	-	-
Erigeron peregrinus	-	-	-	1	3	+	+	+	1	3	+	-	1	1	-	-	-	-	-	-
Parnassia fimbriata	-	-	-	-	1	4	3	-	2	-	-	-	-	-	2	-	-	-	-	-
Sibbaldia procumbens	-	-	-	-	3	3	-	+	+	+	+	+	+	1	1	-	-	-	-	-
Achillea millefolium	-	-	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Myosotis alpestris	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Arnica cordifolia	-	-	-	-	1	3	1	1	-	-	-	-	-	-	-	-	-	-	-	-
Ranunculus eschscholtzii	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Juncus drummondii	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-
Cassiope mertensiana	-	-	-	-	-	22	85	57	-	21	-	-	-	-	-	-	-	-	-	-
Phyllodoce glanduliflora	-	-	-	-	-	+	25	59	88	68	31	1	32	20	2	-	-	-	-	-
Aquilegia flavescens	-	-	-	-	-	-	-	-	+	1	-	-	-	-	-	-	-	-	-	-
Campanula lasiocarpa	-	-	-	-	-	-	-	-	+	+	+	-	-	-	+	-	-	-	-	-
Selaginella densa	-	-	-	-	-	-	-	-	1	+	+	+	1	+	-	1	-	-	-	-
Dryas integrifolia	54	60	48	+	-	-	-	-	-	+	-	17	1	2	1	30	66	68	20	49
Dryas octopetala	-	-	-	-	-	-	-	-	-	-	+	8	-	10	4	-	-	-	-	-
Cassiope tetragona	-	-	-	-	-	-	-	-	-	-	43	51	78	30	60	26	16	4	-	-
Aconitum delphinifolium	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Festuca brachyphylla	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
Carex nardina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-
Oxytropis podocarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1	4
Erigeron compositus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
Smelowskia calycina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

* 5 consecutive quadrats (nos. 1-5, 6-10, etc.)

**3 consecutive quadrats (nos. 96-98)

Zygadenus elegans. As the meadow grades into the *Phyllodoce - Cassiope mertensiana* ct (segments 6 - 14), showy herbs such as *Erigeron peregrinus, Castilleja occidentalis* and *Artemisia norvegica* augment the species composition. As a result the transition zone between these two ct's is the richest in vascular species.

The *Phyllodoce - Cassiope mertensiana* portion has numerous character species, e.g. *Artemisia norvegica, Salix arctica, Erigeron peregrinu*[illegible] *Sibbaldia procumbens* and *Parnassia fimbriata*. This ct overlaps the *Cassiope tetragona - Dryas octopetala* ct above it (segments 11 - 18). Some species, like *Campanula lasiocarpa* and *Selaginella densa*, are restricted to this transition zone. *Dryas octopetala* and *Aconitum delphinifolium* are character species for the *Cassiope tetragona* ct.

Finally, a small area of rock tundra was sampled (segments 18 - 20). Species richness is low in this *Dryas integrifolia - Oxytropis podocarpa* ct, but a number of the characteristic rock tundra species appear here for the first time — *Oxytropis podocarpa, Carex nardina, Festuca brachyphylla* and *Erigeron compositus*.

Bare rock cover is significant only in the rock tundra segment, but bare soil is found throughout. Mosses achieve their greatest cover in the meadow ct with lesser, but still notable, amounts in parts of the *Phyllodoce* ct. Terricolous lichens have their highest cover in the meadow and in the *Cassiope tetragona* ct.

Since the ends of this transect melt out first, it is not surprising that certain species cover values and site characteristics have bimodal distributions.

?

Plate 14. Transect #2 in a depression on R4. The transect starts in the center of the depression in a *Dryas integrifolia* - *Hedysarum alpinum* meadow (bright green), crosses a *Phyllodoce glanduliflora* - *Cassiope mertensiana* community (yellow-green), a *Cassiope tetragona* - *Dryas octopetala* community (brown) and terminates in *Dryas integrifolia* - *Oxytropis podocarpa* Rock Tundra which surrounds the depression. The actual Rock Tundra which was sampled is not shown in the photograph. (Aug. 13,1976)

Soils

The alpine soils of Prospect Mountain have usually developed on coarse limestone and dolomite colluvium derived from the mountain peak. The bedrock of sandstone and shale usually lies only 30 - 50 cm from the surface and forms outcrops in some locations. The soils in the study area are calcareous, characterized by weak horizonation, sandy loam textures, and high organic matter reflected in dark soil colours. Physical and chemical properties of the 29 soil profiles exposed are presented in Table 14. Only 2 soil orders are represented in this alpine area. Regosolic soils are predominant, associated with all but 1 ct. In depressional areas with late snow release and heath vegetation, Brunisolic soils may occur.

The Regosolics belong to 3 main Subgroups. On steep, rocky, poorly vegetated slopes, Orthic Regosols are most common (Plate 15). The horizon sequence varies, consisting of combinations of Ah(k), AC(k) and C(k) horizons. In some areas with a high cover of *Dryas integrifolia*, an H(turf) layer overlies the sandy loam or loamy sand mineral soil. The Ah horizon, although thin, can be very dark, apparently rich in organic matter. Coarse fragments (> 2 mm) are numerous, normally increasing with depth, and large rocks (> 8 cm diameter) are encountered throughout the profile. Free carbonates were detected in many horizons. Only in Orthic Regosols associated with *Cassiope tetragona*-dominated communities is the pH lower (6.8). Orthic Regosols are widespread in most Rock Tundra stands and found occasionally in Heath Tundra and Meadow Tundra as well.

In more mesic areas with higher plant cover, Orthic Humic

Table 14. Physical and chemical properties of some alpine soils from Prospect Mountain.

Community type	Stand No.	Soil Type[1]	Slope and Aspect	Horizon	Depth (cm)	Colour (moist)	pH[2]	% 2-80 mm	% < 2 mm			Text. Class	< 2 mm fraction[3] ppm			meq/100g	% Water < 2 mm basis		% Water whole soil basis	
								coarse	sand	silt	clay		NH_4	NO_3	P	K	1/3 bar	15 bar	1/3 bar	15 bar
1. *D. integrifolia* - *C. rupestris*	1	O.HR.	30°	Ah	0-15	10YR 3/1	7.7	69	64	27	9	SL	1	1	2	0.03	23	10	7	3
			N	AC(k)	15-33	10YR 3/1	7.9	77	68	18	14	SL	0	0	1	0.03	14	6	3	1
	2	O.R.	11° NW	AC(k)	0-15	5Y 3/1	7.9	97	77	19	4	LS	0	1	2	0.02	10	3	0	0
	3	O.HR.	22°	Ahk	0-10	5Y 3/2	8.0	43	70	25	5	SL	1	1	1	0.03	20	9	12	5
			SE	AC(k)	10-30	10YR 3/2	8.0	65	66	26	8	SL	0	0	1	0.02	11	4	4	2
	4	O.HR.	18°	Ahk	0-16	5Y 4/1	7.7	77	68	24	8	SL	1	1	—	0.04	24	12	15	3
			E	AC(k)	16-38	10YR 3/1	7.5	56	54	26	20	SL	1	4	—	0.03	22	9	10	4
2. *D. integrifolia* - *S. alaxensis*	7	O.R.	34°	H	3-0	5Y 2/1	7.4	47	58	28	14	SL	3	1	4	0.05	28	13	15	7
			SE	Ck	0-35	10YR 2/1	7.8	50	54	15	31	SCL	0	0	2	0.04	18	10	9	5
3. *D. integrifolia* - *S. arctica*	8	O.R.	32°	Ah	0-7	10YR 2/1	7.4	49	79	18	3	LS	0	0	8	0.06	19	9	10	4
			NE	AC	7-55	10YR 2/1	7.4	68	67	25	8	SL	0	0	2	0.03	14	7	4	2
4. *D. integrifolia* - *O. podocarpa*	18	O.R.	21°	Ah	0-8	10YR 2/1	7.3	43	68	27	5	SL	18	1	7	0.05	35	19	20	11
			NE	C	8-50	10YR 2/1	7.7	44	58	24	18	SL	0	0	—	0.02	16	10	9	4
	21	O.HR.	28°	Ah	0-18	10YR 3/2	7.5	55	57	27	16	SL	0	0	6	0.04	26	11	12	5
			NW	C	18-45	10YR 3/2	7.5	90	64	19	17	SL	0	0	—	0.04	18	9	2	1
	5	O.HR.	19°	Ah	0-12	10YR 2/1	6.8	83	70	16	14	SL	0	0	—	0.05	18	9	3	2
			N	AC	12-35	10YR 2/1	6.7	47	76	8	16	SL	1	0	14	0.05	22	15	12	8
5. *D. integrifolia* - *C. tetragona*	10	O.HR.	19°	Ah	0-14	10YR 2/1	7.5	50	65	32	3	SL	12	4	—	0.05	48	22	24	11
			NW	AC(k)	14-34	10YR 3/2	7.7	61	60	26	14	SL	0	0	—	0.03	22	10	9	4
				Ck	34-	10YR 3/2	7.3	80												
6. *D. integrifolia* - *H. mackenzii*	17	O.HR.	10°	Ahk	0-12	10YR 2/1	7.4	20	69	26	5	SL	12	2	3	0.03	31	13	25	11
			NE	AC(k)	12-35	10YR 2/1	7.6	79	55	28	17	SL	5	3	3	0.02	35	18	7	4

Table 14. (cont.)

Community type	Stand No.	Soil Type[1]	Slope and Aspect	Horizon	Depth (cm)	Colour (moist)	pH[2]	% 2-80 mm	< 2 mm			Text. Class	< 2 mm fraction[3]				% Water			
													ppm			meq/100g	< 2 mm basis		whole soil basis	
								coarse	sand	silt	clay		NH_4	NO_3	P	K	1/3 bar	15 bar	1/3 bar	15 bar
7. *D. integrifolia* - *B. glandulosa*	9	O.HR.	12° NW	Ah	0-12	10YR 2/1	6.9	24	66	31	3	SL	41	3	15	0.10	91	55	69	42
				C	12-45	5Y 3/1	7.2	66	60	29	11	SL	1	0	1	0.02	28	15	10	5
	11	O.HR.	24° NW	Ah	0-12	10YR 2/1	6.4	17	76	16	18	SL	12	1	5	0.06	26	16	22	13
				AC	12-32	5Y 3/2	7.4	43	50	24	26	SCL	0	5	12	0.05	24	13	13	7
				C	32-	10YR 3/2	7.1	44	44	23	33	CL	0	0	1	0.05	24	13	13	8
	19	O.HR.	34° E	Ah	0-38	10YR 3/1	7.3	63	69	22	9	SL	0	0	2	0.04	18	11	7	4
8. *S. arctica* - *H. alpinum*	30	C.HR.	32° NE	Ah1	0-5	10YR 2/1	6.8	19	59	33	8	SL	13	4	4	0.07	57	26	46	21
				Ah2	5-25	10YR 3/2	7.4	46	47	33	20	L	2	0	1	0.02	31	14	17	7
				Ah3	25-40	10YR 3/1	7.4	53	39	35	26	CL	1	0	–	0.03	27	14	13	6
				Ah4	40-65	10YR 3/1	7.5	33	37	38	25	CL	2	1	–	0.03	30	17	20	10
9. *Salix* spp. - *C. tetragona*	26	O.HR.	10° NW	H	4-0	5Y 2/1	6.3	27	64	32	4	SL	20	2	10	0.08	69	37	50	27
				Ah	0-10	5Y 3/1	6.5	34	48	38	14	L	1	0	1	0.03	41	19	27	13
				AC	10-56	10YR 3/1	6.5	12	55	39	6	SL	1	1	–	0.03	49	24	43	2
10. *S. barrattiana* - *T. albiflorus*	16	O.HR.	2° E	Ahk1	0-12	10YR 2/1	7.4	38	50	38	12	L	1	0	0	0.04	27	9	19	6
				Ahk2	12-32	10YR 2/1	7.4	31	58	33	9	SL	0	4	1	0.03	34	13	24	9
	25	O.HR.	26° E	Ah	0->60	10YR 2/1	6.0	32	64	24	12	SL	1	0	3	0.03	32	9	21	6
11. *C. tetragona* *D. octopetala*	13	O.R.	24° E	Ah	0-7	10YR 2/1	7.1	3	54	44	2	SL	4	6	2	0.02	95	59	92	57
				Ck	7-49	5Y 2/1	8.1	49	56	20	24	SCL	0	0	1	0.02	13	5	7	3
	23	O.R.	24° NE	Ah	0-13	10YR 2/1	6.8	44	74	26	1	LS	2	0	–	0.03	52	27	29	15
				AC	13-51	10YR 3/1	7.2	44	67	25	8	SL	0	0	–	0.03	23	13	13	7

Table 14. (cont.)

Community type	Stand No.	Soil Type[1]	Slope and Aspect	Horizon	Depth (cm)	Colour (moist)	pH[2]	% 2-80 mm	% < 2 mm			Text. Class	< 2 mm fraction[3]				% Water			
													ppm			meq/100g	< 2 mm basis		whole soil basis	
								coarse	sand	silt	clay		NH_4	NO_3	P	K	1/3 bar	15 bar	1/3 bar	15 bar
12. *P. glanduliflora* - *C. mertensiana*	15	O.MB.	30°	Ah	0-12	10YR 2/1	5.7	5	58	40	2	SL	40	2	7	0.05	94	63	89	60
			NE	Bm	12-28	10YR 3/3	6.8	16	44	40	16	L	2	0	0	0.03	34	17	28	14
				Ck	28-40	10YR 3/2	7.9	70	68	19	13	SL	2	1	1	0.02	14	7	4	2
13. *S. arctica* - *S. nivalis*	31	O.HR	0°	Ah	0-41	10YR 3/1	7.7	35	55	28	17	SL	1	2	1	0.03	30	13	19	8
14. *D. integrifolia* - *H. alpinum*	6	O.R.	8°	Ah	0-9	5Y 3/1	7.5	48	58	34	18	SL	3	3	2	0.04	26	11	14	6
			SE	Ck	9-29	10YR 3/2	7.6	34	42	24	24	L	0	0	1	0.04	23	13	15	9
	20	O.R.	12°	H	7-0	10YR 2/1	7.1	58	–	–	–	–	30	10	–	0.12	91	43	38	18
			NW	Ck	0-33	5Y 2/2	7.4	56	49	22	29	CL	2	1	1	0.04	22	12	10	5
	22	O.HR.	26°	Ah	0-18	10YR 3/1	7.1	28	68	26	6	SL	31	2	8	0.07	44	23	32	17
			NE	C	18-41	5Y 3/2	7.4	51	52	29	19	SL	2	0	3	0.04	25	15	17	8
	24	O.HR.	22°	Ah	0-17	10YR 3/1	7.3	53	57	35	8	SL	0	0	1	0.03	37	18	17	8
			NW	C	17-42	10YR 2/1	7.1	14	63	35	2	SL	32	3	4	0.04	90	43	77	37
	29	O.HR.	14°	H	4-0	10YR 2.5/1														
			NE	Ah	0-60	10YR 3/1	7.0	21	45	20	15	L	2	0	1	0.02	43	18	34	14
15. *E. innovatus* - *M. paniculata*	27	O.HR.	14°	Ah	0-15	10YR 2/1	5.8	38	76	12	12	SL	1	0	14	0.05	13	7	8	4
			SE	AC	15-60	5Y 3/1	5.8	42	88	7	5	S	2	1	10	0.05	13	7	7	4
16. *A. norvegica* - *A. flavescens*	28	O.HR.	22°	Ah	0-30	10YR 3/1	5.7	33	70	14	16	SL	0	0	–	0.07	15	8	10	3
			E	C	30->50	10YR 3/1	5.8	38	54	18	28	SCL	0	0	–	0.02	15	8	9	5

[1] Soil Types: O.R. (Orthic Regosol), O.HR. (Orthic Humic Regosol), C.HR. (Cumulic Humic Regosol), O.MB. (Orthic Melanic Brunisol).

[2] pH in water paste

[3] available NH_4, NO_3 and P measured in ppm (soil), exchangeable K measured in meq/ 100g soil.

Regosols dominate. Their physical characteristics are similar to those of the Orthic Regosols, but the Ah horizon is thicker under the lusher vegetation, greater than 60 cm in one site. The pH range is wider, extending from 5.7 in lush Herb Meadows to 8.0 in some Rock Tundra stands. Orthic Humic and Orthic Regosols are very similar and grade into each other, even within a single ct. Orthic Humic Regosols are more common, though, under Shrub Tundra and Meadow Tundra communities.

Cumulic Humic Regosols form the final Regosolic Subgroup. Not of common occurrence, these soils are found only in solifluction areas, e.g. ct 8. The deep profiles are built up through deposition of soil by mass wasting rather than through horizon development into the parent material. Horizons (Ah1, Ah2, Ah3, etc.) can be differentiated by the amount of coarse material, bands of unmixed gravel and buried undecomposed organic matter of aerial origin. Clay content increases with depth, as does pH. There is little colour change between the horizons; all are black to dark grey.

The Brunisolic soils belong to 2 Great Groups, Melanic Brunisols and Eutric Brunisols, and are found only under vegetation dominated by heaths, especially *Phyllodoce glanduliflora*. In depressional areas with high plant cover the soils are Orthic Melanic Brunisols. The horizons are well developed and differentiated – a thick Ah underlain by a brown to reddish brown Bm and grey Ck horizon. There is a steep pH gradient from 5.7 at the surface to 7.9 in the Ck horizon. The coarse fraction also increases sharply from 5% at the surface to 70% at the base of the profile.

On moist, steep slopes covered with *Phyllodoce*, downslope soil movement has caused churning of the soil profile. Ah and Bm horizons

Plate 15. An Orthic Regosol (Ah, Ck) under *Dryas*-dominated Rock Tundra.

Plate 16. A turbic Melanic Brunisol under *Phyllodoce*-dominated plant cover. The Bm (orange) and Ah (black) horizons are mixed by downslope movement. Below them is a Ck horizon.

are mixed but still discernable, forming a turbic Melanic Brunisol (Plate 16).

In heath-dominated areas with less plant cover, on drier, steeper slopes, the Ah horizon is thinner and the Orthic Melanic Brunisols grade into Orthic Eutric Brunisols. This soil change often occurs in the transition zone between *Phyllodoce*- and *Cassiope tetragona*--dominated communities. Surface pH values are higher than in the Melanic Brunisols and there is less of a pH gradient within the soil profile. The surface coarse fraction is also larger. Bm horizons are dark brown, thin and sometimes discontinuous. The Orthic Eutric Brunisols form a narrow transition from the Orthic Melanic Brunisols in the deep, snow accumulating, heath hollows to the Orthic Regosols of the surrounding Rock and Shrub Tundra. This soil type is not characteristic of any ct and was, therefore, not sampled.

In general, soil nutrient concentrations are low (Table 14). Nitrate (NO_3) concentration is particularly low, often 0 or 1 ppm with a maximum of 10 ppm in one meadow community. Ammonia (NH_4) values vary widely, from 0 - 41 ppm. The larger values, for both compounds, are mainly characteristic of the surface horizons. Average concentration of $N0_3$ in Ah or H horizons is 1.6 ppm as compared to 0.8 ppm in subsurface layers. For NH_4 the values are 7.8 and 2.0 respectively.

The amount of available phosphorus (P) and exchangeable potassium (K) in the soil is also small; P achieves a maximum of 15 ppm and K a maximum of 0.12 meq/100 g. The surface horizons have slightly higher concentrations than the underlying horizons, 4.5 cf. 3.3 ppm for P, and 0.05 cf. 0.03 meq/100 g for K.

The amount of water held by the soil at 1/3 and 15 bar tension is expressed in Table 14 both as a percentage of oven-dry weight of the < 2 mm fraction, and of the whole soil. The very low values for percent water on a whole soil basis are a result of both low moisture retention of the < 2 mm fraction and the large coarse fraction present. The moisture retention of most samples is quite low; high values are obtained only for the surface horizons rich in organic matter. The lowest values were recorded for Rock Tundra soils. Combined with generally steep slopes, this results in dry soil for much of the growing season and significant leaching in times of rain. Poor moisture retention is also characteristic of the soils of the *Elymus* - *Mertensia* and *Artemisia* - *Aquilegia* Herb Meadow communities. In the field, however, these soils are quite moist due to the concave local topography and the constant supply of water all summer from a nearby snowbank. Meadow, Shrub and Heath Tundra soils usually have higher percent water values, at both 1/3 and 15 bar tension, than the Rock Tundra soils.

Meteorological Observations

The complex topography of the mountain, the steep ridges and valleys with different altitudes and exposures, causes some temperature, vapour pressure deficit and wind pattern variation in the study area. The measurements taken at the single meteorological station, therefore, serve only as an indication of the general macrometeorological conditions. The study period discussed is June 10 to August 28, 1976.

Temperature

The recording hygrothermograph gave a continuous record of air temperature at ground level (sensor at 7 cm) for the study period. A max-min thermometer was used to help calibrate the hygrothermograph but, as the former instrument had to be replaced twice, there were extended intervals for which no data were available from it. Therefore the hygrothermograph record was used to calculate monthly means of daily maximum, minimum and mean temperature, which are presented in Table 15. Daily values are shown graphically in Figure 27.

Table 15. Monthly means of daily mean, maximum and minimum temperatures in °C on Prospect Mountain for June to August, 1976.

	Mean	Maximum	Minimum
June (10 - 30)	4.0	8.3	-0.3
July (1 - 31)	8.0	12.0	3.9
August (1 - 28)	7.4	10.9	3.9
June - August	6.7	10.6	2.8

There was little difference in mean daily maximum, minimum and mean temperatures for July and August. June was considerably colder, however, with a mean minimum for the month below freezing, and a monthly mean temperature of only 4.0 °C. The maximum temperature for the summer, 19 °C, occurred on July 16, and the minimum of - 4 °C on

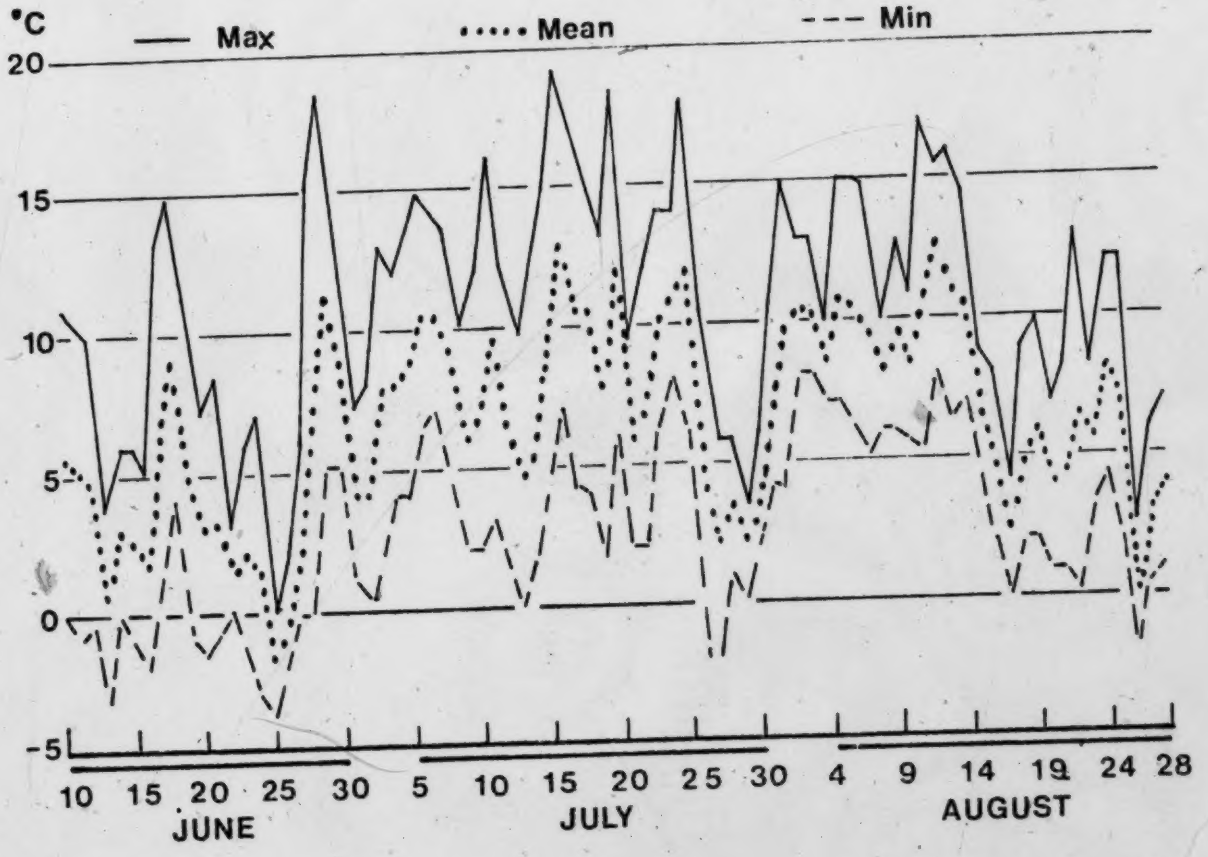


Fig. 27. Daily maximum, minimum and mean temperature, Prospect Mountain, summer 1976.

June 25. The only period with sustained high mean daily temperatures extended from July 31 to August 15. The mean diurnal range was small (8.3 C^{o}) and relatively constant for the study period.

Freezing temperatures were recorded on 26 days during the study period; June had 17 days ≤ 0 °C, July had 5 and August 4.

Vapour Pressure Deficit

Mean daily vapour pressure deficits (VPD's), calculated as the average of VPD at 6 hour intervals, were low (Fig. 28). The range for the study period was 0 - 10.3 mb with a mean of 2.5 mb. The maximum mean daily VPD of 10.3 was recorded on July 16, the day on which the absolute maximum temperature of 19 °C was attained. Minimum values of 0 mb were noted often, both as individual measurements and daily means, usually during and after periods of precipitation. On some days, when no precipitation fell, fog and heavy cloud enveloping the mountain resulted in a relative humidity of almost 100% and a VPD of 0 mb.

VPD varies with temperature during the day. Highest VPD readings occur during periods of high temperature and low relative humidity, usually around midday. The absolute maximum VPD value measured was 14.0 mb, at 1200 hrs on July 16. Night values were characteristically lower.

VPD was lower during June with an average of 1.0 mb. Cool temperatures and high rainfall for the month contributed to the low values. Daily means exceeded 2.0 mb on only 3 days, June 17, 28 and 29. The mean monthly VPD for July was higher at 3.8 mb, due to the higher mean temperature and higher maxima recorded. The only extended period

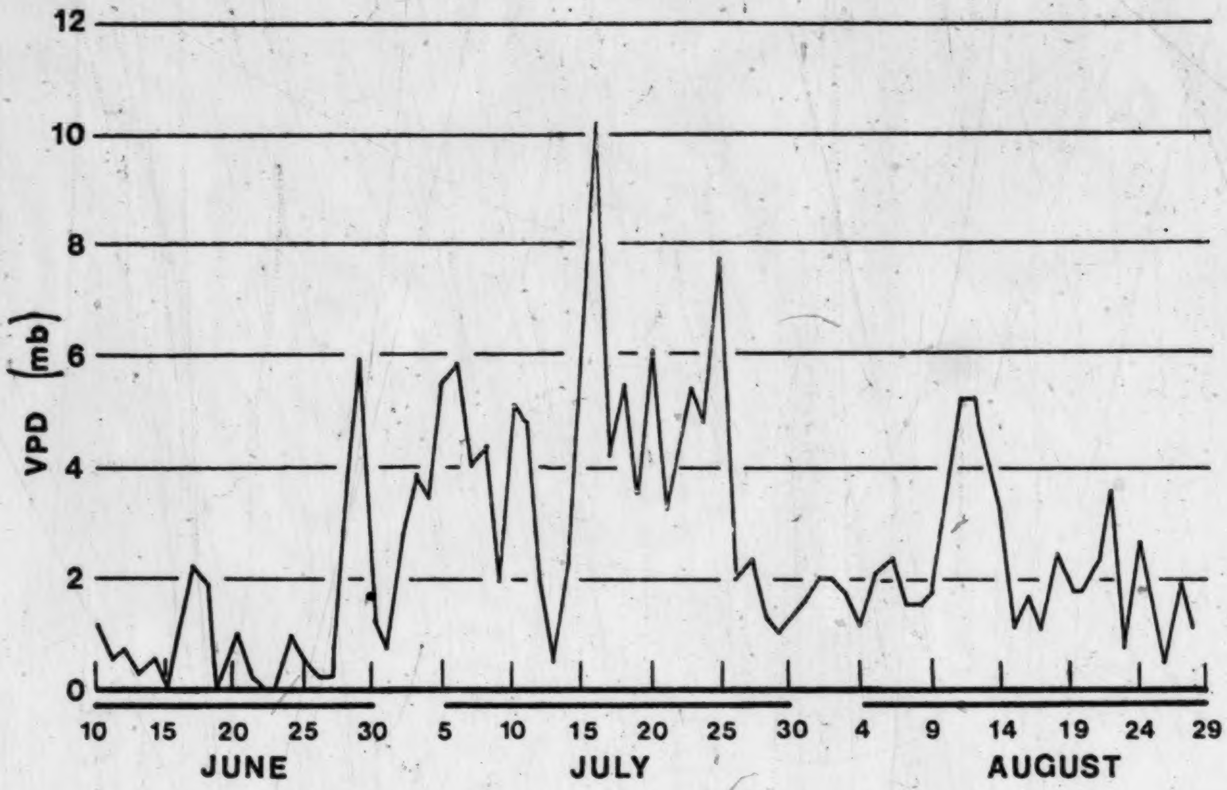


Fig. 28. Mean daily vapour pressure deficit, Prospect Mountain, summer 1976.

with VPD's above average was July 14 to 26 ($\bar{x}$ VPD = 5.2), which coincided with a period without precipitation. The mean VPD for August, 2.2 mb, is intermediate between the values for June and July; this was the wettest month of the 3 but had temperatures equivalent to those in July. An above average VPD of 4.6 mb was recorded for the dry period of August 11 to 14.

Wind

The wind blew almost constantly in the alpine on Prospect Mountain, usually from the N or NW but occasionally from the S or SE. Mean weekly wind speeds are plotted in Figure 29. Relatively low wind speeds occurred in mid-June, mid-July and early August. The mean monthly wind speed for June was 14.1 km/hr, for July 12.6 km/hr, and for August 12.1 km/hr.

Readings were taken every 1 - 3 days and the wind speed over these intervals calculated. The highest wind speeds for such an interval were 38 km/hr on July 27 - 28 and 43 km/hr on August 16 - 17.

Each time the meteorological station was visited the mean wind speed over a 10 minute time span was measured. The highest short interval reading was 60 km/hr on August 17. Individual gusts were not measured. August 14 was the calmest day of the study period and the only time the anemometer was observed to be stationary.

Precipitation

A total of 287 mm of precipitation fell during the study period: 72 mm in June, 75 mm in July and 140 mm in August.

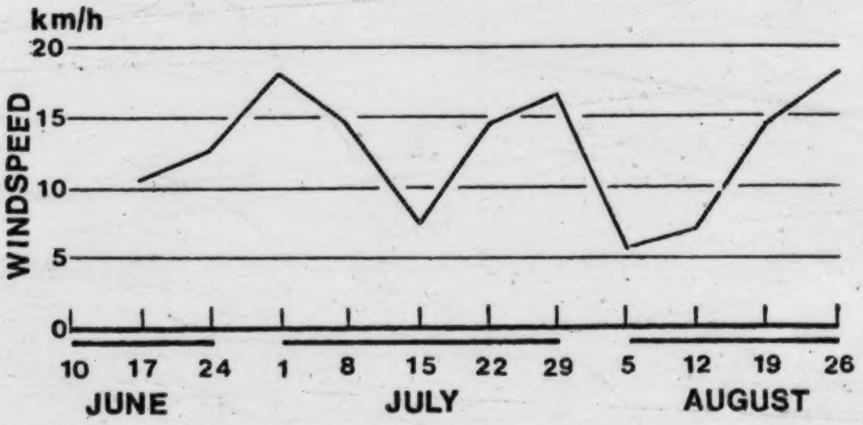


Fig. 29. Mean weekly wind speed, Prospect Mountain, summer 1976.

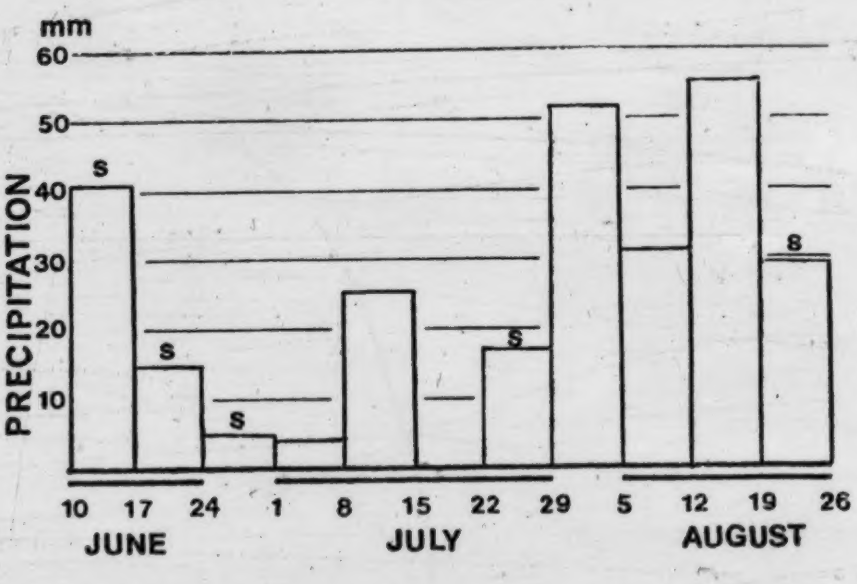


Fig. 30. Weekly precipitation, Prospect Mountain, summer 1976.
S - weeks during which snow fell.

The weekly distribution of precipitation over the summer is shown in Figure 30. The only extended period without rain was July 14 - 26. The heaviest 2-day rainfall of 55 mm occurred on August 15 - 17, culminating a period of heavy and sustained precipitation from July 22 to August 16. This caused the spring runoff channels on the mountain to once again fill with water. Some erosional damage was caused by these streams and by Prospect Creek, which became choked with silt.

Snow fell in all 3 months but did not contribute significantly to precipitation totals. The snowfalls observed on June 12, 25, July 27 and August 17 were light, nocturnal, and soon melted during the day. A heavy snowfall on June 17 remained on the ground for 3 days and impeded access to the study area. Light snow flurries which melted on impact were common during the study period.

No exact figures are available for annual snowfall at Prospect, but the general area receives more than 20 cm (water equivalent; Atlas of Alberta 1969). Despite this large amount, the alpine slopes on Prospect were snow-free by mid-May 1976, as a result of wind action and the overall eastern exposure. Only the heath hollows and snowbeds remained covered on this date. Subalpine areas, however, were not completely released from snow until mid to late June.

The monthly precipitation totals for Grave Flats Lookout, 25 km to the SE, are very similar to those for Prospect in 1976 (Table 16). The Grave Flats figures for 1976 are slightly less than the 30-year calculated means for the site. It is tentatively concluded that the summer precipitation in the study area in 1976 was also slightly below average.

Table 16. Summer precipitation totals (mm) for Prospect Mountain and Grave Flats Lookout.

	Prospect 1976	Grave Flats[1] 1976	Grave Flats[2] 1941 - 1970
June	72.2[3]	50.9[3]	100.3
July	75.3	77.7	111.0
August	139.8	135.0	90.4
Total	287.3	263.6	301.8

[1] Alberta Forest Service (unpublished)

[2] Environment Canada (1975)

[3] June 10 - 30 only

B. COMPARISON WITH THE ALPINE TUNDRA OF THE MALIGNE RANGE

Flora

Floristic Similarity

Meaningful comparison of floristic similarity between alpine sites is often complicated by the use of different criteria for defining the alpine zone. For Prospect Mountain, Bald Hills (Kuchar 1975) and Signal Mountain (Hrapko 1970), however, the same criteria were used. The vascular floras of the two Maligne sites have a high percent similarity (see METHODS, page 24) to each other, 81%, and are equally dissimilar to that of Prospect Mountain; 58% for Signal and 56% for Bald Hills.

The floristic similarity of these three sites to other Alberta Rocky Mountain alpine sites, Snow Creek (Beder 1967), Bow Summit (Broad 1973), Highwood Pass (Trottier 1972), Wilcox Pass (Crack 1977) and Ram Mountain (Johnson 1975), was also examined (Table 17; Fig. 31). The floristic similarities generally range from 48% to 59%, indicating a regional alpine flora common to all. The highest similarities were found between Signal and Bald Hills (81%), Prospect and Wilcox Pass (68%), and Prospect and Ram Mountain (67%). Sites with low floristic similarity are Bald Hills and Bow Summit (43%), Prospect and Bow Summit (48%), Ram Mountain and Signal (49%), and Ram Mountain and Bald Hills (49%).

Distribution Within Families

The vascular plant species found on Prospect Mountain belong to 34 families, as compared to 30 for Signal Mountain and 33 for Bald Hills.

Table 17. Percent vascular flora similarity* between Alberta Rocky Mountain alpine study areas. References cited in text; locations in Figure 31.

	Prospect	Signal	Bald Hills
(1) Prospect	—	58	56
(2) Signal	58	—	81
(3) Bald Hills	56	81	—
(4) Ram Mountain	67	49	49
(5) Wilcox Pass	68	58	57
(6) Bow Summit	48	55	43
(7) Snow Creek	57	50	59
(8) Highwood Pass	58	52	57

* expressed as 200(species in commun/ total species)

Fig. 31. The geographical locations of the study areas for which floristic similarity was calculated. Reference numbers refer to Table 17.

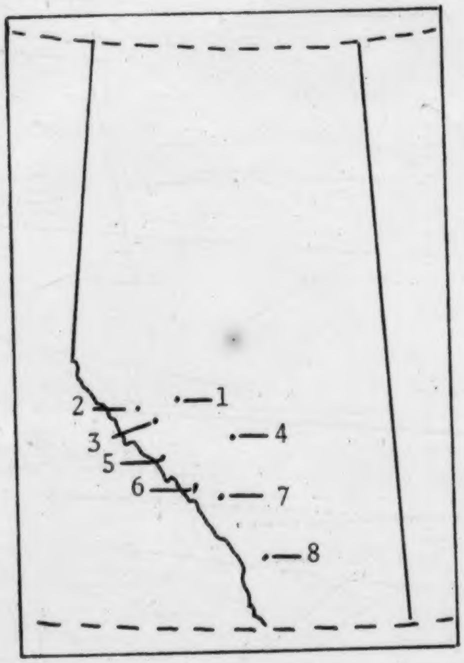


Table 18. Species distribution within families in the Prospect (P), Signal (S), and Bald Hills (BH) study areas.

Family	No. of Species			% Total Flora		
	P	S	BH	P	S	BH
Ophioglossaceae	0	1	1	0	1	1
Polypodiaceae	1	1	3	1	1	2
Equisetaceae	3	1	1	2	1	1
Lycopodiaceae	0	4	4	0	3	2
Selaginellaceae	1	1	1	1	1	1
Pinaceae (+ Cupressaceae)	4	4	4	2	3	2
Gramineae	16	16	20	8	11	10
Cyperaceae	14	14	23	7	9	12
Juncaceae	3	7	6	2	5	3
Liliaceae	4	2	1	2	1	1
Orchidaceae	1	0	0	1	0	0
Salicaceae	9	4	5	5	3	3
Betulaceae	1	1	1	1	1	1
Polygonaceae	4	2	3	2	1	2
Portulacaceae	1	1	1	1	1	1
Caryophyllaceae	7	6	9	4	4	5
Ranunculaceae	9	9	10	5	6	5
Papaveraceae	1	0	1	1	0	1
Cruciferae	16	6	13	8	4	7
Saxifragaceae	12	9	11	6	6	6
Rosaceae	10	7	11	5	5	6
Leguminosae	11	4	5	6	3	3
Crassulaceae	0	1	1	0	1	1
Empetraceae	0	1	1	0	1	1
Onagraceae	3	2	6	2	1	3
Elaeagnaceae	0	0	1	0	0	1
Umbelliferae	1	0	0	1	0	0
Pyrolaceae	3	4	0	2	3	0
Ericaceae	6	10	10	3	7	5
Caprifoliaceae	1	0	0	1	0	0
Primulaceae	2	1	1	1	1	1
Gentianaceae	3	3	3	2	2	2
Hyrophyllaceae	1	0	0	1	0	0
Boraginaceae	2	1	1	2	1	1
Scrophulariaceae	8	8	7	4	5	4
Valerianaceae	1	0	1	1	0	1
Campanulaceae	3	2	1	2	1	1
Compositae	27	20	30	14	14	15
Total Species	191	151	197			
Total Families	34	30	33			

The 4 most important families in terms of species richness are the same on Prospect and Bald Hills: Compositae, Gramineae, Cruciferae and Cyperaceae, although the order is different on each. On Signal Ericaceae replaces Cruciferae and is the fourth largest family.

The actual breakdown of species into families, both numerically and as a percentage of the total flora, is presented in Table 18. Although most families make up a similar percentage of the vascular flora in all three locations, some important differences should be noted. Prospect is completely lacking in members of Lycopodiaceae, whereas Signal and Bald Hills have four species each. Prospect also lacks Crassulaceae and Empetraceae, families which have one species each at the Maligne sites. Families present in the alpine on Prospect, although in small amounts, but absent on Signal and Bald Hills are Orchidaceae, Umbelliferae, Caprifoliaceae and Hydrophyllaceae.

Families which are significantly larger at Prospect, both in number of species and percentage of flora, include Salicaceae, Cruciferae (cf. Signal only) and especially Leguminosae. Families with the graminoid growth-form, Graminae, Cyperaceae and Juncaceae, form a smaller percentage of the Prospect flora. There are also fewer species of Ericaceae on Prospect, mainly due to the absence of the genus *Vaccinium.*

Phytogeography

The vascular floras of Signal Mountain and Bald Hills were divided into phytogeographical classes as was done for Prospect Mountain (page 37). The class assigned to each species is recorded in Appendix III. The percentage frequency distributions of the flora in these classes for the three study areas are compared in Table 19.

Table 19. Frequency distribution of vascular species from the three study areas in the major distribution classes. For an explanation of the distribution types (1 - 9) see page 37.

Distribution Type	% Total Flora Prospect	Signal	Bald Hills
Arctic-Alpine			
North American (1)	14	10	6
Circumpolar (2)	25	30	26
Total	39	40	32
Amphi-Beringian (3)	6	9	9
Cordilleran			
Widespread (4)	13	19	18
Northern (5)	5	3	3
Southern (6)	7	9	11
Total	25	31	32
Rocky Mountain Restricted (7)	4	2	5
Low-elevation			
North American (8)	13	5	8
Circumboreal (9)	14	14	14
Total	27	19	22
Disjuncts	12	3	2

Generally, the frequency distributions are very similar. A larger percentage of the Prospect flora is made up of low-elevation species, mainly North American low-elevation species. The circumboreal element is constant. For the arctic-alpine classes, there is also a higher percentage of continentally restricted species on Prospect, but here the circumpolar element is slightly smaller. There are also fewer Amphi-Beringian species on Prospect.

Overall there are slightly fewer Cordilleran species on Prospect. Reduced numbers of widespread and southerly-centered species account for this. There is a slightly higher percentage of northerly-centered Cordilleran species on Prospect.

The greatest difference between the Prospect and Maligne areas occurs, not for one of the nine basic phytogeographical classes, but in the number of species with disjunct distributions. For Prospect 12% of the flora can be described as disjunct compared to 3% for Signal and 2% for Bald Hills. The disjunct species found on Signal are *Carex petricosa, Ranunculus gelidus, Pyrola grandiflora, Campanula uniflora* and *Pedicularis flammea.* Bald Hills disjuncts are *Carex misandra, Ranunculus gelidus, Erysimum pallasii* and *Papaver kluanensis.* Of these disjuncts only *Ranunculus gelidus* and *Erysimum pallasii* are not found at Prospect. *R. gelidus* is a Cordilleran species, scattered throughout its range, and *E. pallasii* is a circumpolar arctic-alpine species with isolated southern populations.

Species Richness

The total number of vascular species reported for Signal and Bald Hills, 151 and 197 respectively, are similar to the total for Prospect at 191.

Species richness can also be examined and compared at both the ct and quadrat level. The average number of species per ct for each of the major vegetation groups common to the 3 study areas are presented in Table 20. In most cases the Prospect ct's contain a larger number of vascular species. The Prospect and Signal Rock Tundra communities, which cover large areas at both locations, have similar species richness values. The Heath Tundra communities, which are floristically similar for the 3 study areas (see page 144), are very much richer on Prospect. The small area covered by each Heath Tundra stand on Prospect results in a greater influx of species characteristic of the surrounding communities. However, possible differences in the delineation, size and sampling intensity of the stands in the 3 study areas must also be considered when comparing the values in Table 20.

Comparison at the 25 X 25 cm quadrat level is less subject to deviation due to variation in sampling approach of individual workers. The average number of vascular plants per quadrat for the major vegetation groups on Prospect and Signal are presented in Table 21; no data are available for Bald Hills. The values for the Heath Tundra and Snowbed Tundra are almost equal for the 2 areas and those for the Rock Tundra and Meadow Tundra are slightly higher at Signal.

Table 20. Average number of vascular species per community type for the major tundra vegetation groups on Prospect, Signal and Bald Hills.

	Prospect	Signal	Bald Hills
Rock Tundra	29	31	19
Heath Tundra	39	29	18
Snowbed Tundra	30	20	14
Meadow Tundra	43	30	29

Table 21. Average number of vascular species per quadrat for the major tundra vegetation groups on Prospect and Signal. Bald Hills data were not available.

	Prospect	Signal
Rock Tundra	4.1	6.8
Heath Tundra	8.6	8.8
Snowbed Tundra	6.0	6.0
Meadow Tundra	8.0	10.0

High-Presence Alpine Species

The high-presence species on Signal and Bald Hills are different from those on Prospect (see page 36). On Signal *Artemisia norvegica* is the most widespread species (stand presence = 100%), followed by *Salix arctica, Polygonum viviparum, Campanula lasiocarpa* (92%); *Potentilla diversifolia* (83%); *Salix nivalis* (75%); *Poa alpina, Poa arctica, Dryas octopetala* and *Silene acaulis* (67%).

On Bald Hills *Artemisia norvegica* is also the most widespread (80%), followed by *Campanula lasiocarpa* (70%); *Carex nigricans* (67%); *Antennaria lanata, Poa arctica, Festuca brachyphylla* (63%); *Sibbaldia procumbens, Luzula spicata* (60%); *Carex spectabilis* and *Potentilla diversifolia* (53%). Five of the 10 most widespread species on Bald Hills are graminoids as compared to 2 for Signal and only 1 for Prospect.

The species which exhibit the highest average stand presence in all three areas are *Salix arctica* (71%); *Potentilla diversifolia* (67%); *Artemisia norvegica, Polygonum viviparum* (66%); *Salix nivalis* (64%); *Poa arctica, Poa alpina* and *Silene acaulis* (54%).

Vegetation

Cluster Analysis

To study the relative similarities of stands from the 3 study areas, their distribution amongst the various clusters of a combined 73-stand cluster hierarchy was examined, both overall and at the 8-cluster level. The numbers assigned to the Signal and Bald Hills stands for this comparative study are presented in Tables 22 and 23. Nomenclature for the Signal community types from the most recent treatment of the

Table 22. Stand numbers assigned to Signal Mountain community types for computer analysis. Community type names are from Hrapko (1970); synonymous names from Hrapko and La Roi (1978) are added parenthetically.

Stand No.[1]	ct[2]	Signal Mountain ct (Hrapko 1970)
32	A	*Dryas octopetala* on scree *(Dryas octopetala - Oxytropis podocarpa)*
33	B	*Dryas octopetala* - graminoid *(Dryas octopetala - Festuca brachyphylla)*
34	C	*Dryas octopetala - Kobresia bellardii* *(Dryas octopetala - Kobresia bellardii)*
35	D	*Dryas octopetala* - lichen *(Dryas octopetala - Salix nivalis*
36	E	*Dryas octopetala* - moss *(Dryas octopetala - Pedicularis capitata)*
37	F	*Cassiope tetragona - Dryas octopetala* *(Cassiope tetragona - Dryas octopetala)*
38	G	*Dryas octopetala - Empetrum nigrum* *(Dryas octopetala - Empetrum nigrum)*
39	H	*Dryas octopetala - Salix arctica* *(Dryas octopetala - Salix arctica)*
40	J	*Cassiope mertensiana - Phyllodoce glanduliflora* *(Cassiope mertensiana - Phyllodoce glanduliflora)*
41	K	*Salix arctica - Arctagrostis arundinacea* *(Salix arctica - Arctagrostis arundinacea)*
42	L	*Salix arctica - Antennaria lanata* *(Salix arctica - Antennaria lanata)*
43	M	*Carex nigricans* *(Carex nigricans - Luzula wahlenbergii)*

---

[1] used in this thesis

[2] used in Hrapko (1970) and Hrapko and La Roi (1978)

Table 23. Stand numbers assigned to Bald Hills community types and subtypes for computer analysis.

Stand No.[1]	ct[2]	Bald Hills ct or st name[2]
46,47,48,49,50	1	*Dryas octopetala* - lichen ct
45	2	*Dryas octopetala* - *Polytrichum piliferum* ct
44	4	*Artemisia norvegica* - *Dryas octopetala* ct
72,73	5	cushion-rosette ct
51,52,53	8	*Cassiope tetragona* - *Dryas octopetala* ct
54,55	8b	*Cassiope tetragona* - *Phyllodoce glanduliflora* st
69	8c	*Lepraria neglecta* st
57,58,59	9	*Phyllodoce glanduliflora* - *Cassiope mertensiana* ct
56	9b	*Phyllodoce glanduliflora* st
61	9c	*Cassiope mertensiana* st
60,62	10	*Luetkea pectinata* ct
63,64	11	*Artemisia norvegica* - *Salix arctica* ct
65	12	*Artemisia norvegica* - *Luzula parviflora* ct
66	13	*Artemisia norvegica* - *Anemone occidentale* ct
67,68	14	*Artemisia norvegica* - *Antennaria lanata* ct
70,71	15	*Carex nigricans* ct

---

[1] used in this thesis

[2] used in Kuchar (1975); ct's 3, 6 and 7 were not sampled quantitatively

vegetation (Hrapko and La Roi 1978) are included.

The qualitatively based cluster analysis of the 3 study areas shows a compositional dichotomy between the Prospect stands and those of the Maligne Range (Fig. 32). The magnitude of this floristic difference is illustrated by the high coefficient (1.629) at which the 2 main clusters finally join. The Signal and Bald Hills stands are mixed, however, even at the lowest fusion levels. The 73 stands have formed 8 clusters at a coefficient of 0.238. The 31 Prospect stands make up 5 of these clusters and the 42 Maligne stands account for the other 3. Of the 5 Maligne stand clusters, 1 is composed solely of Signal stands and 2 of both Bald Hills and Signal stands.

A similar dichotomy is not obvious in the quantitatively based fusion hierarchy (Fig. 33). Although there is more mixing of stands in the quantitatively based dendrogram, most of the Prospect stands are still remote from the Maligne stands. Of the clusters formed at the 8--cluster level (coefficient = 2.317) 3 are composed entirely of Prospect stands. The *Dryas integrifolia*-dominated stands from Prospect cluster early and join the other stands of the 3 study areas only with the final fusion. The Shrub and Meadow Tundra stands from Prospect also seem very dissimilar to any Signal or Bald Hills stands and are separate at the 8-cluster level. The *Phyllodoce glanduliflora*- and *Salix arctica*--dominated stands from Prospect cluster with their counterparts from Signal. The *Cassiope tetragona*-dominated stands from all 3 study areas cluster to form a major group at this level. The rest of the Maligne stands do not cluster with Prospect stands until higher cluster levels.

Dryas integrifolia, which is so dominant in so many Prospect communities, is completely absent on Bald Hills and Signal, and the reverse

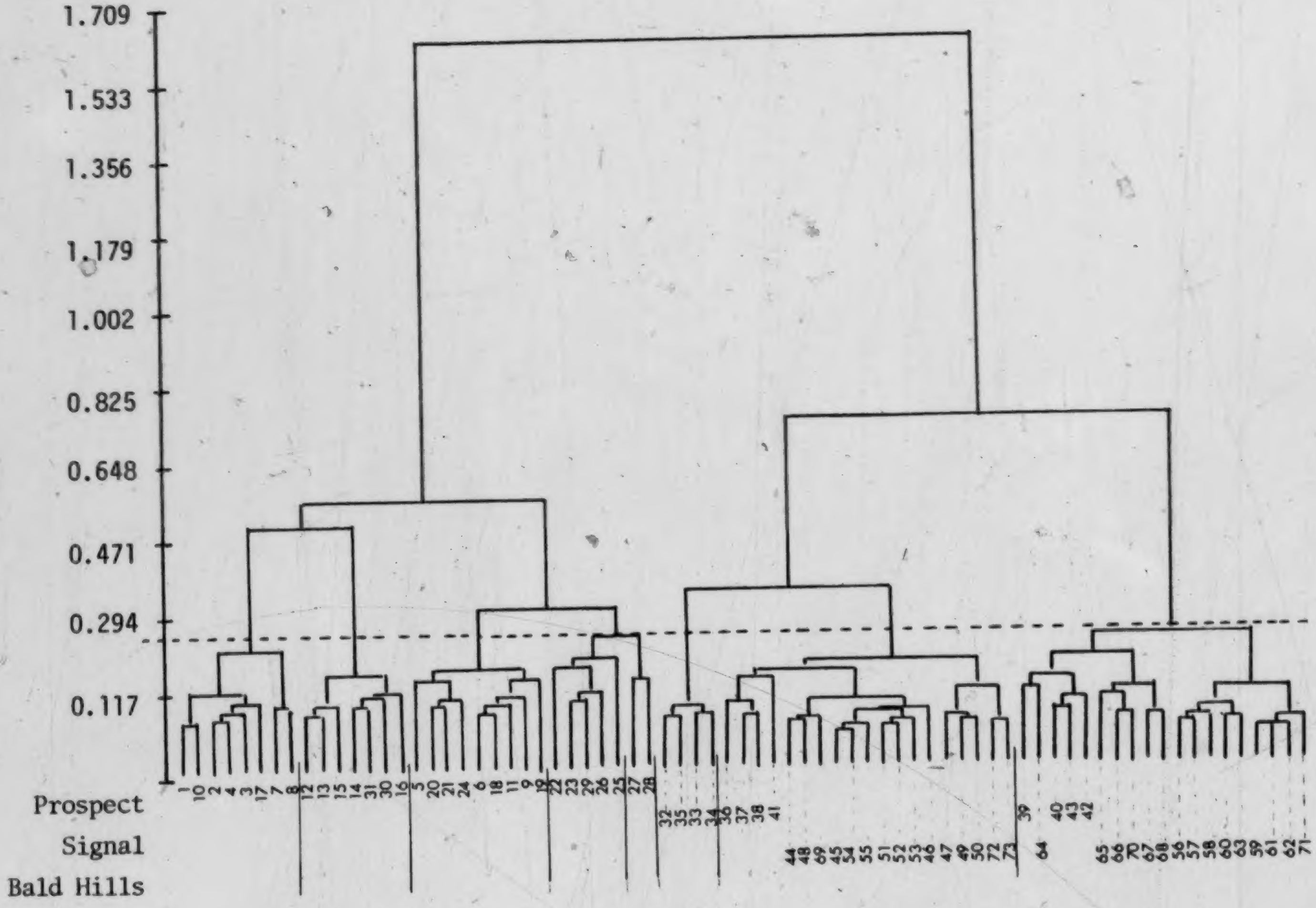


Fig. 32. Cluster dendrogram of Maligne Range and Prospect stands based on qualitative data.

Fig. 33. Cluster dendrogram of Maligne Range and Prospect stands based on quantitative data.

General composition of the clusters at the 8-cluster level:

(1) Prospect — *Dryas integrifolia*-dominated Rock Tundra stands

(2) Prospect — *Dryas integrifolia*-dominated Meadow Tundra and Shrub Tundra stands

(3) Prospect and Signal — *Phyllodoce glanduliflora*- and *Salix arctica*-dominated stands

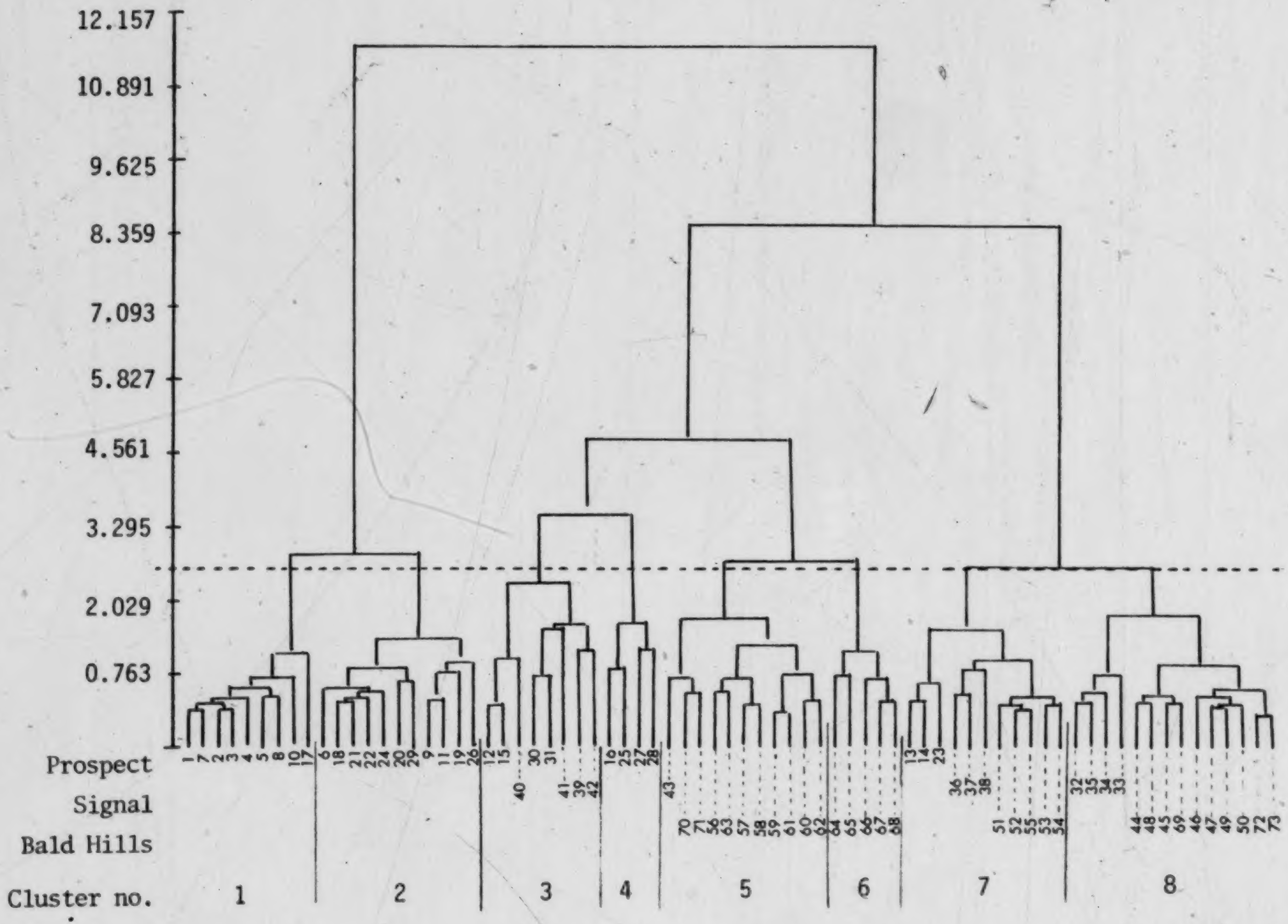
(4) Prospect — *Salix barrattiana*-dominated and Herb Meadow stands

(5) Signal and Bald Hills — *Carex nigricans*-dominated stands
Bald Hills — *Phyllodoce glanduliflora*- and *Luetkea pectinata*-dominated stands

(6) Bald Hills — *Artemisia norvegica*-dominated stands

(7) Prospect, Signal and Bald Hills — *Cassiope tetragona*--dominated stands

(8) Signal and Bald Hills — *Dryas octopetala*-dominated Rock Tundra stands


12.157
10.891
9.625
8.359
7.093
5.827
4.561
3.295
2.029
0.763
Prospect
Signal
Bald Hills
Cluster no.
1 7 2 3 4 5 8 10 17
6 18 21 22 24 20 29 9 11 19 26
12 15 40 30 31 41 39 42
16 25 27 28
43 70 71 56 63 57 58 59 61 60 62
64 65 66 67 68
13 14 23 36 37 38 51 52 55 53 54
32 35 34 33 44 48 45 69 46 47 49 50 72 73
1
2
3
4
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7
8

is almost true for *Dryas octopetala*. To study the influence of the quantitative contribution of these 2 species on the cluster composition, the stands were clustered with them removed (Fig. 34). The greatest effect is on Rock Tundra stands. Stands of this group from all 3 study areas now form a single cluster at the 8-cluster level. However, even at high fusion levels, the Prospect Meadow and Shrub Tundra stands cluster only with each other. Heath Tundra, Rock Tundra and Snowbed Tundra stands of Prospect are grouped with similar stands from the Maligne Range at the 8-cluster level, but they maintain their geographic integrity at the lower fusion levels and often cause a large increase in ESS with fusion. For example, *Cassiope tetragona*-dominated stands 10, 13, 14 and 23 of Prospect join the *C. tetragona* stands of Signal and Bald Hills at the 11-cluster level (coefficient = 1.705), and *Phyllodoce glanduliflora* stands 12 and 15 of Prospect join the Signal *P. glanduliflora* stands at the high 7-cluster level (coefficient = 2.083).

Therefore, considering species composition and species structure, with or without *Dryas* species included, and at all fusion levels, most Rock Tundra, Shrub Tundra and Meadow Tundra stands on Prospect are very dissimilar to those of the Maligne Range.

Comparison of Ecologically Equivalent Communities

Using the quantitative and qualitative ct descriptions in this thesis, those of Hrapko (1970) and Kuchar (1975), and the cluster analyses of the proceeding section, equivalent communities were determined for Prospect, Signal and Bald Hills (Table 24). The ecologically equivalent communities are of two kinds, floristic and physiognomic equivalents. The "floristic equivalents", i.e. ct's similar in physical habitat,

Fig. 34. Cluster dendrogram of Maligne Range and Prospect stands based on quantitative data without *Dryas* species.

General composition of the clusters at the 8-cluster level:

(1) Prospect, Signal and Bald Hills – Rock Tundra stands

(2) Prospect, Signal and Bald Hills – *Cassiope tetragona*-dominated stands

(3) Prospect – *Dryas integrifolia*-dominated Meadow and Shrub Tundra stands

(4) Prospect – *Salix barrattiana*-dominated and Herb Meadow stands

(5) Prospect – *Phyllodoce glanduliflora*-dominated stands

(6) Signal – Heath and Meadow Tundra stands

(7) Signal and Bald Hills – *Carex nigricans*-dominated stands
Bald Hills – Heath Tundra stands

(8) Bald Hills – *Artemisia norvegica*-dominated Meadow Tundra stands

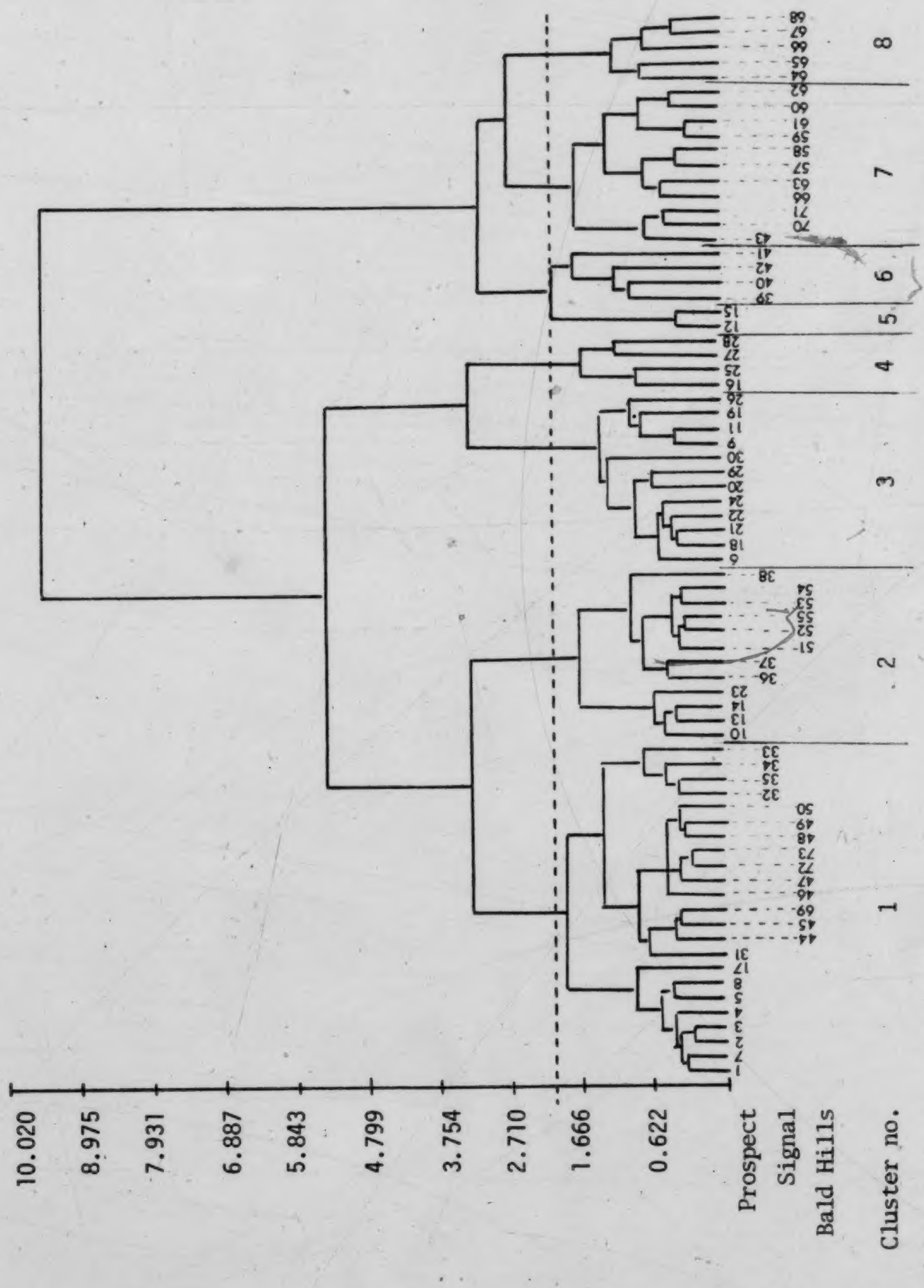

10.020
8.975
7.931
6.887
5.843
4.799
3.754
2.710
1.666
0.622
Prospect
Signal
Bald Hills
Cluster no.
1
2
3
4
5
6
7
8

Table 24. Maligne Range community types floristically (f) or physiognomically (p) equivalent to Prospect community types. Index of similarity (IS) is calculated with and without *Dryas* species.

Prospect ct	type	Signal ct (Hrapko 1970)	IS_{ps} w:wo *Dryas*	type	Bald Hills ct (Kuchar 1975)	IS_{pb} w:wo *Dryas*
Rock Tundra						
1. *Dryas integrifolia* - *Carex rupestris*	p	*Dryas octopetala* - *lichen*	2:6	p	*Dryas octopetala* - *lichen*	1:2
2. *Dryas integrifolia* - *Salix alaxensis*	p	*Dryas octopetala* islands	3:11		ne*	
3. *Dryas integrifolia* - *Salix arctica*		ne			ne	
4. *Dryas integrifolia* - *Oxytropis podocarpa*		ne			ne	
4a. *Kobresia* st	f	*Dryas octopetala* - *Kobresia bellardii*	17:40	f	*Kobresia***	
5. *Dryas integrifolia* - *Cassiope tetragona*	p	*Dryas octopetala* - moss	7:25		ne	
6. *Dryas integrifolia* - *Hedysarum mackenzii*	p	*Dryas octopetala* - graminoid	1:2		ne	
Shrub Tundra						
7. *Dryas integrifolia* - *Betula glandulosa*	p	*Dryas octopetala* - *Empetrum nigrum*	5:12		ne	
8. *Salix arctica* - *Hedysarum alpinum*	f	*Dryas octopetala* - *Salix arctica*	30:36	f	*Artemisia norvegica* - *Salix arctica*	33:33
9. *Salix* spp. - *Cassiope tetragona*		ne			ne	
10. *Salix barrattiana* - *Trollius albiflorus*		ne		f	*Salix barrattiana* scrub**	
Heath Tundra						
11. *Cassiope tetragona* - *Dryas octopetala*	f	*Cassiope tetragona* - *Dryas octopetala*	68:70	f	*Cassiope tetragona* - *Dryas octopetala*	43:45
12. *Phyllodoce glanduliflora* - *Cassiope mertensiana*	f	*Cassiope mertensiana* - *Phyllodoce glanduliflora*	50:59	f	*Phyllodoce glanduliflora* - *Cassiope mertensiana*	47:47
ne		ne			*Luetkea pectinata*	
Snowbed Tundra						
13. *Salix arctica* - *Salix nivalis*	f	*Salix nivalis***		f	*Lepraria neglecta* st	41:41
ne		*Carex nigricans*			*Carex nigricans*	
ne		ne			*Poa cusickii*	
ne		ne			*Luzula* snowbed	
Meadow Tundra						
14. *Dryas integrifolia* - *Hedysarum alpinum*		ne		p	*Artemisia norvegica* - *Dryas octopetala*	4:7
15. *Elymus innovatus* - *Mertensia paniculata*		ne			ne	
16. *Artemisia norvegica* - *Aquilegia flavescens*	p	*Salix arctica* - *Antennaria lanata*	11:11	f	*Artemisia norvegica* - *Salix arctica*	26:26
ne		*Salix arctica* - *Arctagrostis arundinacea*			ne	
ne		ne			*Artemisia norvegica* - *Luzula parviflora*	
ne		ne			*Artemisia norvegica* - *Anemone occidentale*	
ne		ne			*Artemisia norvegica* - *Antennaria lanata*	
Other Communities						
rock outcrop**		cushion plants**			cushion rosettes	

---

[*] no equivalent

[**] not sampled

physiognomy, species composition and species structure, may belong to the same or closely related associations. The "association" as defined by Flahault and Schröter (1910) and translated by Pavillard (1935) is "... a plant community of definite floristic composition, presenting a uniform physiognomy, and growing in uniform habitat conditions." The "physiognomic equivalents", ct's similar in physiognomy and physical habitat but not floristics, may belong to the same or closely related formation. However, the "formation", a vegetation classification unit defined by physiognomy and structure, particularly growth-form (Beard 1973), is more generally used on a continental scale than the regional one considered here. To determine the degree of floristic similarity of these ct's, the quantitative index of similarity (IS; see METHODS) was calculated, with and without *Dryas* spp., for equivalent ct's between Prospect and Signal (IS_{ps}) and Prospect and Bald Hills (IS_{pb}) and is presented in Table 24.

Rock Tundra

The Rock Tundra communities of all three study areas are strongly dominated by *Dryas* spp., *D. integrifolia* on Prospect and *D. octopetala* on Maligne. Because of the sharp difference in dominant species, most Rock Tundra communities are physiognomically but not floristically equivalent.

The *Dryas integrifolia - Carex rupestris* ct of Prospect is physiognomically equivalent to the *Dryas octopetala* - lichen ct's of Signal and Bald Hills. All are found on dry, rocky, exposed slopes and ridgetops, often with patterned ground. Floristically they are very dissimilar, even when the dichotomizng effect of the *Dryas* species is removed (Table 24). The *Arctostaphylos uva-ursi* st described for Bald Hills is similar to the *A. uva-ursi* st on Prospect, although it is much less common and lacks the pronounced terraced topography of the latter.

Dryas octopetala forms discrete islands on scree slopes on Signal and Bald Hills, just as *D. integrifolia* does on Prospect. These islands were sampled separately on Signal but were included in the *Dryas octopetala* - lichen ct for Bald Hills. However, the other species inhabiting these *Dryas* mats are very different in the two areas and the IS between the Signal *Dryas octopetala* islands ct and the Prospect *Dryas integrifolia* - *Salix alaxensis* islands ct is very low (3% with and 11% without *Dryas*).

The *Dryas integrifolia* - *Cassiope tetragona* ct on Prospect is physiognomically equivalent to the *Dryas octopetala* - moss ct on Signal; no equivalent was described on Bald Hills. The *Dryas octopetala* - moss ct is found on rocky solifluction microterraces on Signal which are comparable to the stone steps and small solifluction terraces of the *Dryas integrifolia* - *Cassiope tetragona* ct. *C. tetragona* and *Salix arctica* occupy depressional areas in both ct's and mosses are abundant under the shrubby vascular layers. A low IS of 7% with *Dryas* is increased to 25% without *Dryas* as the 2 ct's have many common species.

The *Dryas integrifolia* - *Oxytropis podocarpa* ct has no equivalent on either Maligne study area, but the *Kobresia bellardii* st can be considered floristically equivalent to the *Dryas octopetala* - *Kobresia bellardii* ct of Signal and the described, but not sampled, *Kobresia* ct of Bald Hills. The *Kobresia bellardii* st has a fairly high IS of 40% (without *Dryas*) to the *Dryas octopetala* - *Kobresia* ct, because of its high *Kobresia* cover; associated species do vary significantly. When all the stands of the *Dryas integrifolia - Oxytropis podocarpa* ct are considered, however, this IS drops to 18%. The *Dryas octopetala - - Kobresia* and *Kobresia* ct's have characteristically lower species richness, lower species vitality, and a harsher physical environment than the *Kobresia* st on Prospect. The *Dryas integrifolia - Oxytropis podocarpa* ct as a whole is more mesic, with a higher bryophyte cover, higher species richness and more heavily vegetated stripes and terraces than the Maligne *Kobresia* communities.

The *Dryas integrifolia - Hedysarum mackenzii* ct on Prospect is physiognomically equivalent to the *Dryas octopetala* - graminoid ct on Signal. Both are characterized by an almost continuous *Dryas* mat with an open layer of graminoids above. However, the species encountered are completely different. On Signal *Dryas octopetala* is found in association with *Festuca brachyphylla, Agropyron latiglume* and *Carex petricosa,* while on Prospect the *Dryas integrifolia* is mixed with *Carex rupestris, C. scirpoidea, C. nardina* and *C. petricosa.* As well, *Hedysarum mackenzii,* which is not found in the Signal study area, is the subdominant in the *Dryas integrifolia - Hedysarum mackenzii* ct on Prospect. The low floristic similarity is shown by the low IS_{ps} = 1% with, and 2% without *Dryas* included.

The *Dryas integrifolia - Salix arctica* (sandstone scree) ct on Prospect has no equivalent on Signal or Bald Hills. The *Dryas octopetala - Polytrichum piliferum* ct of Bald Hills has no alpine equivalent on Prospect but it was found in the forest tundra zone which was not sampled on Prospect.

Shrub Tundra

The *Dryas integrifolia - Betula glandulosa* ct on Prospect has no floristic equivalent on either Signal or Bald Hills. The *Dryas octopetala - Empetrum nigrum* ct occupies small solifluction terraces on Signal as on Prospect, and is dominated by low shrubs, and as such could be considered to be physiognomically equivalent. The dominant shrub species in each ct is absent from the other and indeed *E. nigrum* is completely absent from the Prospect study area. *Betula glandulosa*-dominated communities have not been found in either of the Maligne study areas, though the species occurs in small patches above timberline there (G. La Roi pers. comm.). The IS_{ps} of 12% is similar to the IS of physiognomically equivalent Rock Tundra communities.

The *Salix arctica - Hedysarum alpinum* ct of Prospect is similar to two Maligne ct's. The *Dryas octopetala - Salix arctica* ct on Signal occupies the same habitat, i.e. large solifluction risers, and is quite floristically similar (IS_{ps} = 30%). The Bald Hills *Artemisia norvegica - Salix arctica* ct, also similar floristically (IS_{pb} = 33%), is generally found on gentle well-watered slopes, although elements of this ct sometimes occur at the base of solifluction risers. The risers themselves on Bald Hills are covered with the *Artemisia norvegica - Antennaria lanata* ct which is dissimilar in species composition, structure and physiognomy and was therefore rejected as an equivalent in favour of the *Artemisia - Salix arctica* ct. As well as having a high cover of *Salix arctica*, all three ct's are rich in showy herbs and have a high vascular plant cover. *Hedysarum alpinum*, which is the subdominant on Prospect, does not occur in this ct on Signal and was not found in the Bald Hills study area.

The *Salix barrattiana - Trollius albiflorus* ct covers significant areas of alpine streamsides and slopes bases on Prospect, and is floristically equivalent to the *Salix barrattiana* scrub ct described for Bald Hills, where it is more commonly found below treeline.

The *Salix* spp. - *Cassiope tetragona* ct of depressional areas on the lower alpine slopes of Prospect has no Maligne equivalent.

Heath Tundra

The Heath Tundra Group has floristically equivalent ct's on the Maligne Range and Prospect. The *Cassiope tetragona - Dryas octopetala* ct on Prospect is very similar to the *Cassiope tetragona - Dryas octopetala* ct's on Signal and Bald Hills, including the *Cassiope tetragona - Phyllodoce glanduliflora* st on Bald Hills. All are found in similar habitats and are highly similar in species composition and structure. (IS_{ps} = 68%, IS_{pb} = 43%).

The *Phyllodoce glanduliflora - Cassiope mertensiana* ct, of deep snow accumulation areas on Prospect, is floristically equivalent to the *Cassiope mertensiana - Phyllodoce glanduliflora* ct, including the *C. mertensiana* and *P. glanduliflora* st's, on Bald Hills. Although small patches dominated solely by *C. mertensiana* or *P. glanduliflora* were found on Prospect, they were not sampled separately. The three ct's are similar in species composition and structure (IS_{ps} = 59%; IS_{pb} = 47%). This community is restricted to small depressions on Prospect but covers extensive areas in the Maligne Range, especially on Bald Hills.

The *Luetkea pectinata* ct on Bald Hills has no Prospect or Signal equivalents and *Luetkea* itself has not been found in the latter two study areas.

Snowbed Tundra

The sole snowbed community on Prospect, the *Salix arctica - Salix nivalis* ct, most closely resembles the *Salix nivalis* ct described for late snow release sites on Signal. As no quantitative sampling was done for the latter ct, no IS can be calculated. The *Lepraria neglecta* st of the *Cassiope tetragona - Dryas octopetala* ct on Bald Hills is also very similar (IS_{pb} = 41%). Both this st and the Prospect snowbed ct are found in depressional areas of late snow release, have fine soil covered by crustose lichens, have *Salix arctica* as the dominant vascular plant, and have other common species as well. Therefore they are designated as floristically equivalent communities.

The most common snowbed community in the Maligne Range is the *Carex nigricans* ct, which was not found on Prospect Mountain; *C. nigricans* itself was absent from the study area. Two minor snowbed types described but not sampled for Bald Hills, the *Luzula* and *Poa cusickii* ct's, are also absent on Prospect.

Meadow Tundra

The *Dryas integrifolia - Hedysarum alpinum* ct on Prospect is physiognomically equivalent to the *Artemisia norvegica - Dryas octopetala* ct of Bald Hills. They occur on topographically similar sites and have similar physiognomies — a nearly continuous *Dryas* carpet with an open herb layer above it. Floristically they are dissimilar, though, (IS_{pb} = 4% with, and 7% without *Dryas*). The *Dryas integrifolia - Hedysarum alpinum* ct also differs in having a more mesic habitat, higher bryophyte cover, and more species-rich herb assemblage. The Prospect ct has been classified as a Meadow Tundra community in the *Dryas* Meadow Subgroup, but both it and the Bald Hills ct could also be considered as intermediates between the Rock Tundra and Herb Meadow Groups.

The *Artemisia norvegica - Aquilegia flavescens* ct is physiognomically equivalent to the *Salix arctica - Antennaria lanata* ct on Signal and floristically equivalent to the *Artemisia norvegica - Salix arctica* ct on Bald Hills. Found on gentle slopes with a constant water supply, all have lush herb cover and similar species compositions. The *Artemisia - - Salix arctica* ct has a higher similarity (IS_{pb} = 26% cf. IS_{ps} = 11%) due to the high cover of *Artemisia.* The *Artemisia - Salix arctica* ct was also considered equivalent to the Prospect *Salix arctica - Hedysarum alpinum* ct on the basis of numerous common subdominant species.

The other *Artemisia norvegica*-dominated ct's on Bald Hills, *Artemisia - Luzula parviflora, Artemisia - Anemone occidentalis* and *Artemisia - Antennaria lanata*, have no Prospect equivalents. The Signal *Salix arctica - Arctagrostis arundinacea* ct, found in mesic-hydric sites, has no equivalent either.

Other Communities

The rock outcrop ct described for Prospect is floristically equivalent to the cushion plant ct described for sandstone rockfaces on Signal, and the cushion rosette ct sampled on Bald Hills. All have similar habitats, low total plant cover, and similar species compositions.

Indirect Ordination

Stands of the three alpine study areas were ordinated together to elucidate environmental gradients which may partially account for differences between communities from Prospect and the Maligne Range.

The coefficient of community (CC; see METHODS page 30) matrix provided the best separation of stands and was used for the final ordination (Fig. 35).

Prospect stands, with the exception of those in the Heath and Snowbed Tundra groups, are well separated at the bottom of this ordination (Fig. 36). At the top of the ordination field many Bald Hills stands are also well separated. In the central area, stands from all three study areas overlap.

A number of environmental factors were plotted on the ordination, and of these soil pH and soil moisture retentivity showed the best correlation. Soil surface pH increases from top to bottom (Fig. 37), from the Bald Hills stands to those from Prospect. Soil moisture retention under 15 and 1/3 bar tensions, and % available moisture (1/3 - 15 bar) all increase towards the top of the ordination. The ordination of available moisture values is shown in Figure 38. Unfortunately no moisture retention values were available for Bald Hills stands.

Available soil nutrients, texture and >2 mm fraction; and total vascular, bryophyte, and lichen cover were also plotted but showed no correlation. Comparable snow release dates or field soil moisture levels were not available from all three sites and therefore could not be plotted on the ordination.

Both indirect ordination results and field observations indicate that soil pH and moisture content are strongly associated with the distribution of stands on the landscape. Available moisture is perhaps not the best reflection of field soil moisture content. In addition, missing Bald Hills data make it unsuitable for use as a gradient.

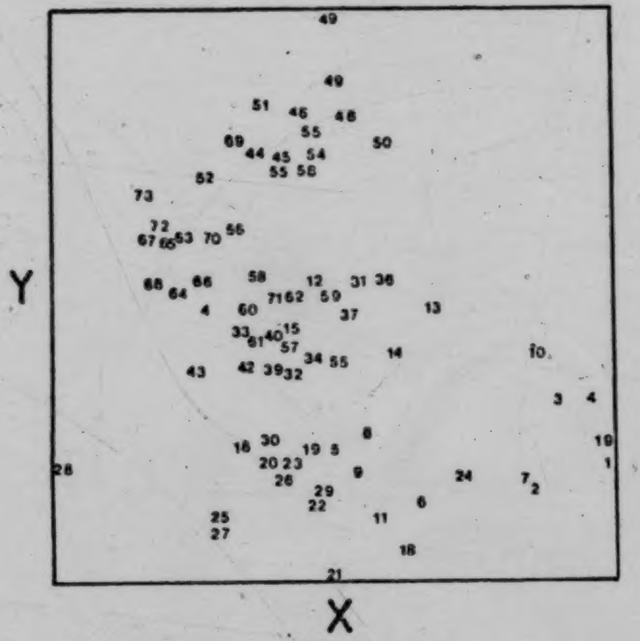


Fig. 35. Bray-Curtis ordination of Prospect (nos. 1-31), Signal (nos. 32-43) and Bald Hills (nos. 44-73) stands using the coefficient of community (see METHODS, page 30). X and Y loci of stands given in Appendix V.

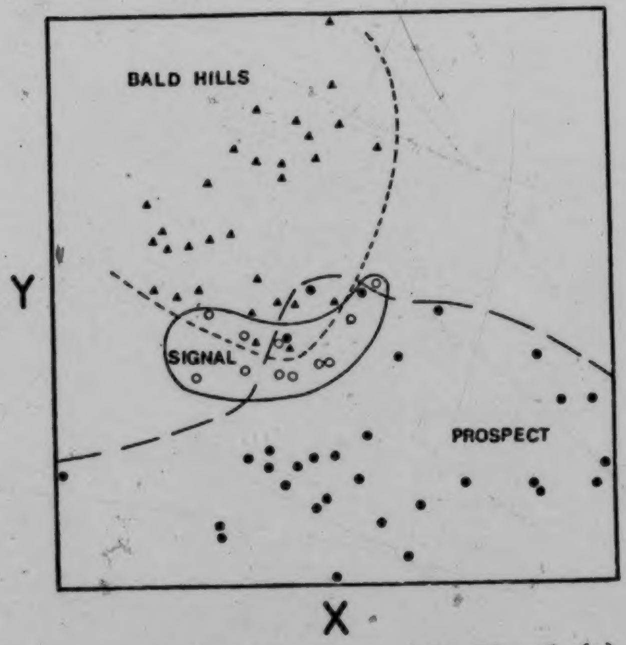


Fig. 36. Distribution of Prospect (•), Signal (o) and Bald Hills (▲) stands on the Bray-Curtis indirect ordination.

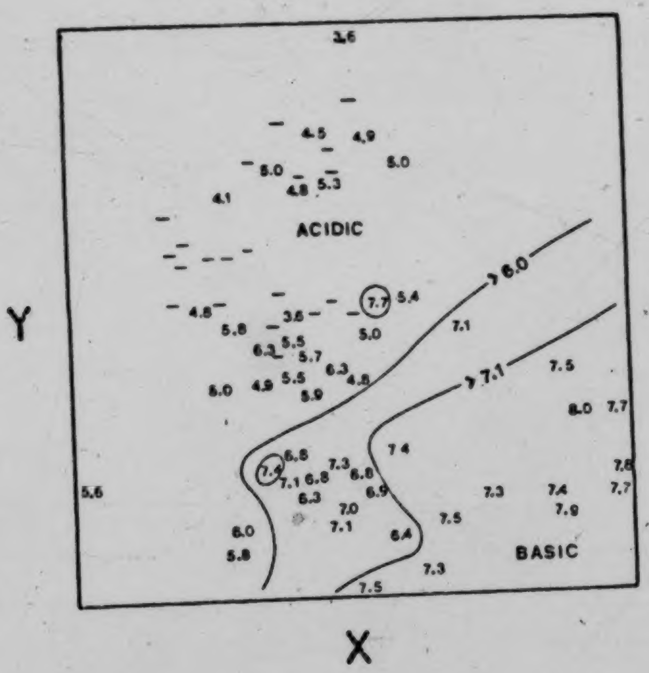


Fig. 37. pH of upper soil horizon on the Bray-Curtis indirect ordination of Prospect, Signal and Bald Hills stands. A dash (-) denotes no data available.

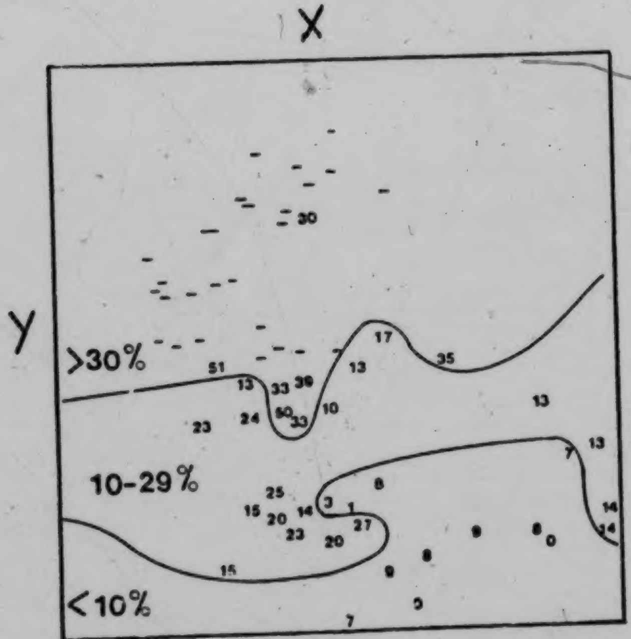


Fig. 38. Available soil water expressed as a percentage of whole soil on the Bray-Curtis indirect ordination of stands. A dash (-) denotes no data available.

Moisture indices and direct ordination methods provide an alternative method for examining the placement of stands along complete soil pH and moisture axes.

Direct Ordination

Ordinations using weighted moisture indices (WMI) and unweighted moisture indices (UMI) as one axis, and soil pH as the other (see METHODS, page 31) are similar and therefore only that based on WMI's is shown (Fig. 39). The stands' WMI's range from 1.7 to 3.5; there are no stands at the hydric end of the gradient. Once again Prospect stands are almost completely separated from the others (Fig. 40), mainly on the basis of soil pH.

All three study areas have similar ranges along the moisture gradient, but Prospect stands extend a little farther into the driest end of the scale. WMI increases as soil pH decreases for Prospect stands. This trend was not observed for the Signal or Bald Hills stands, however. As a result, the Prospect stands at the mesic end of the gradient are situated closer to the Maligne Range stands than are those at the xeric end. This agrees with the results from the IS matrix and cluster analysis which showed the mesic Heath Tundra and Snowbed Tundra communities to have the greatest similarity between the two main study areas.

The quantitatively based clusters at the 8-cluster level (Fig. 33, page 140) separate reasonably well on the ordination (Fig. 40). However some clusters at the mesic end of the ordination do not form cohesive groups. In particular stands dominated by *Cassiope tetragona, Phyllodoce*

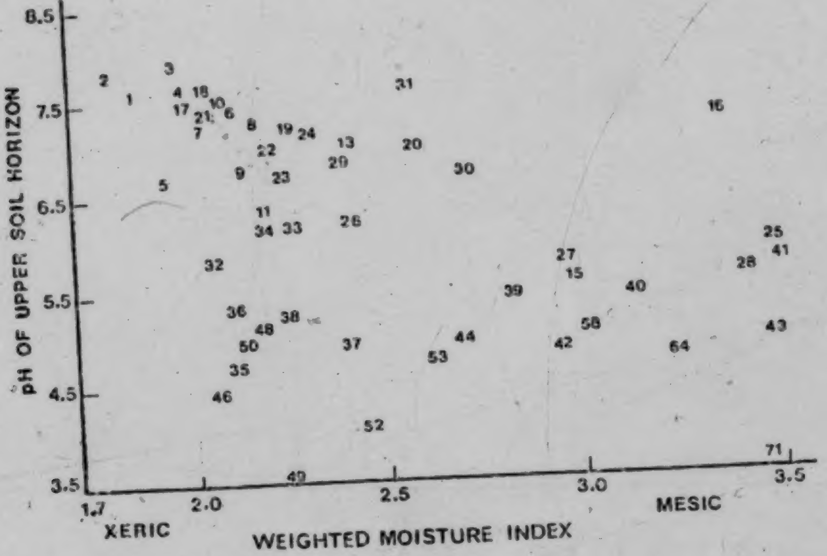


Fig. 39. Direct ordination of Prospect, Signal and Bald Hills stands in relation to soil pH and weighted moisture index.

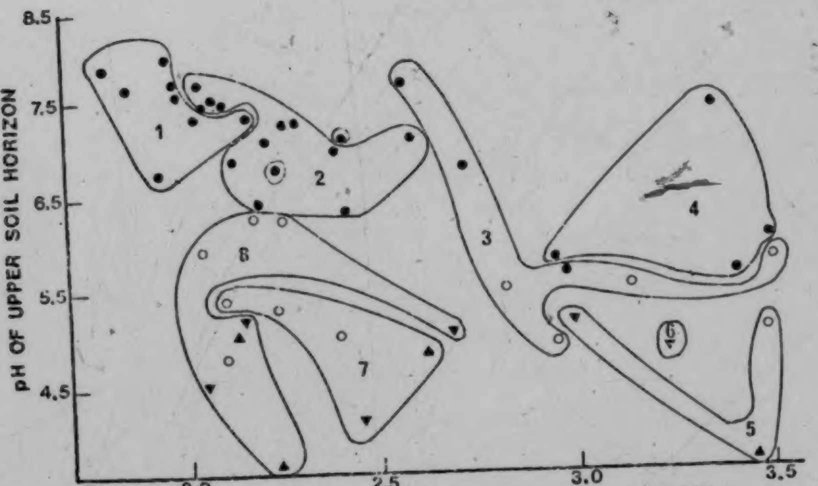


Fig. 40. Distribution of Prospect (●), Signal (o) and Bald Hills (▼) stands on the direct ordination, with quantitative clusters at the 8-cluster level circled and numbered (see Fig. 33, page 140).

glanduliflora and *Salix arctica*, which show considerable physiognomic and ecologic similarity in the three areas, are widely separated on the ordination field. Thus similar ct's do not necessarily have similar WMI and pH ranges in the three study areas. Therefore these two factors may not exert as much influence on the distribution of these ct's on the landscape. Some other environmental factor, e.g. snow depth, may be more closely related.

Individual species distributions are more closely related to these axes (Figs. 41 - 44). The direct ordination can be used to determine the optimum environmental conditions of species. Of particular interest are the quantitatively important species which distinguish the two main areas, i.e. those which are dominant or play an ecologically significant role in one area but not the other. A knowledge of their environmental amplitudes or fundamental niches would help explain their relative abundances in the two ranges.

Dryas integrifolia and *D. octopetala* are of particular interest as they characterize so many Rock Tundra communities in each area. *Dryas integrifolia* (Fig. 41) reaches its highest prominence on dry, alkaline sites, but is also found in the most mesic sites at the higher pH's. *D. octopetala* (Fig. 42) reaches its optimum at a much lower pH and slightly higher WMI than does *D. integrifolia*, and is absent from the mesic sites. *D. octopetala* does occur sporadically on some sites with a higher pH.

Artemisia norvegica (Fig. 43), which is so common on Signal and Bald Hills, attains its highest PV's in the middle of the pH gradient at the mesic end of the ordination, but it is widespread at lower PV's. It is absent only from the drier, high-pH stands.

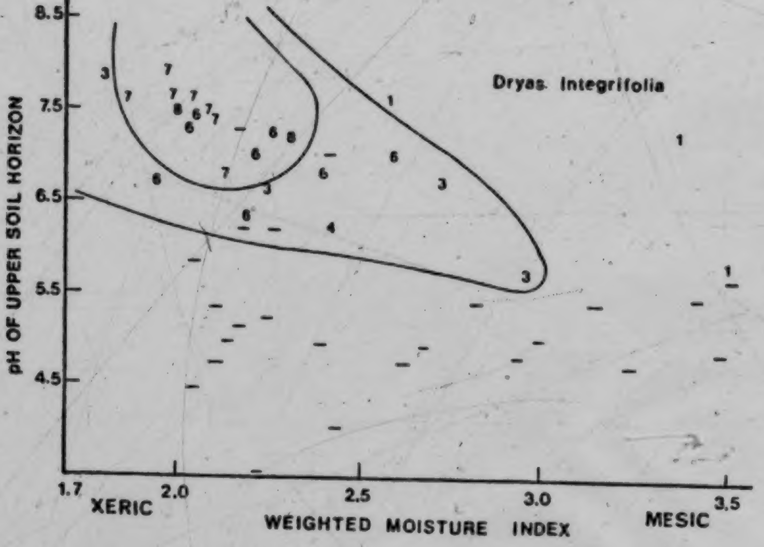


Fig. 41. Distribution of *Dryas integrifolia* coded PV's on the direct ordination. For PV code see page 29.

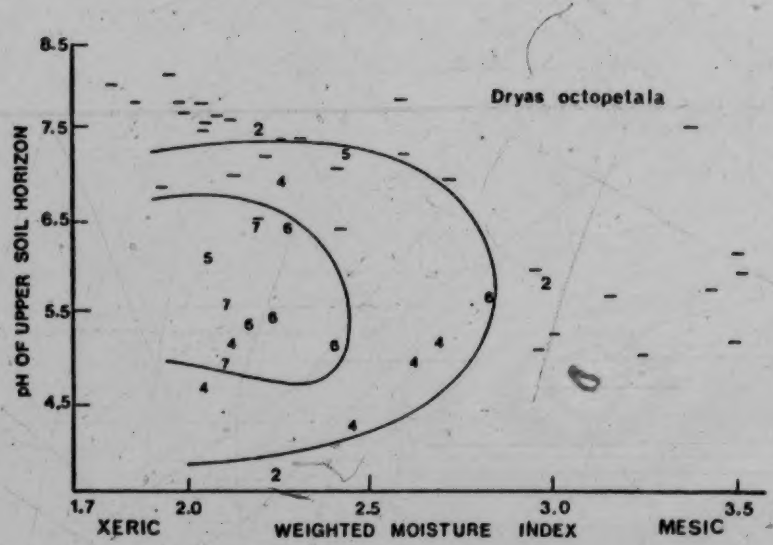


Fig. 42. Distribution of *Dryas octopetala* coded PV's on the direct ordination. For PV code see page 29.

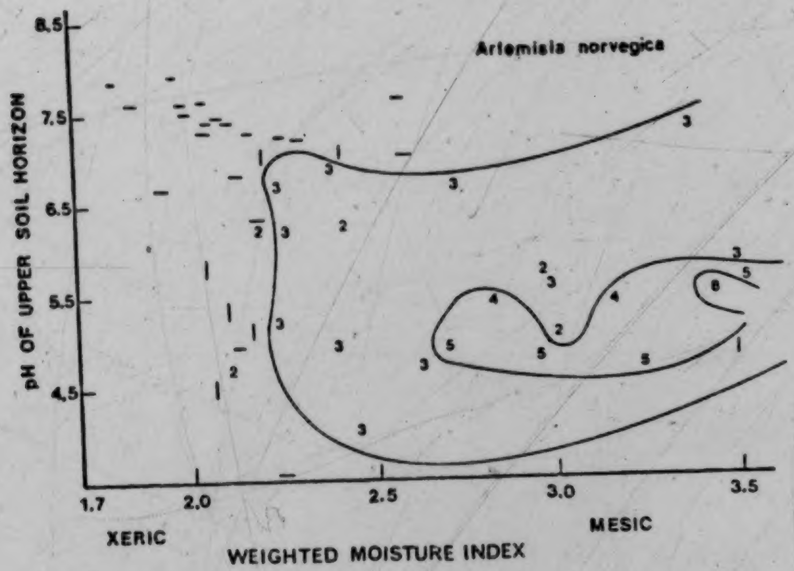


Fig. 43. Distribution of *Artemisia norvegica* coded PV's on the direct ordination. For PV code see page 29.

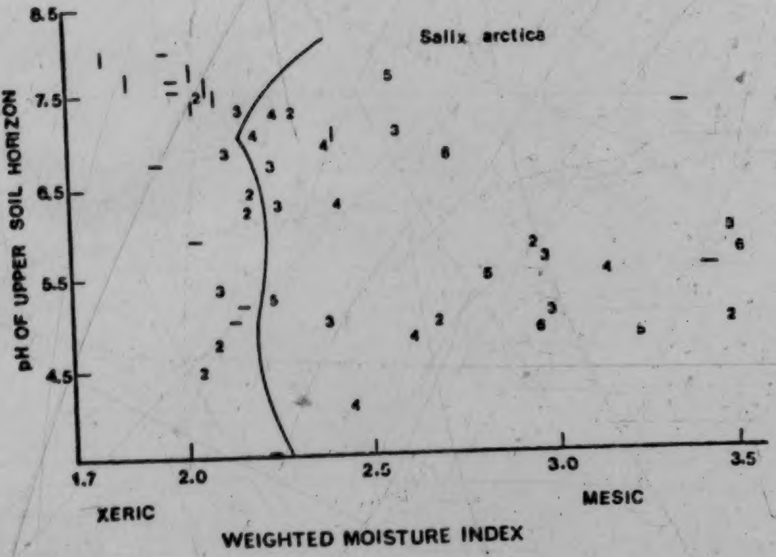


Fig. 44. Distribution of *Salix arctica* coded PV's on the direct ordination. For PV code see page 29.

Salix arctica (Fig. 44) is also widespread and ecologically significant. It has no obvious optimal area on the ordination, and achieves high PV's in stands covering most of the sampled range of soil pH and moisture. It is consistently low in prominence or absent only from the driest stands with a high pH. The prevalence of the drier, high-pH stands on Prospect may account for the restricted distribution of *Artemisia* and *Salix arctica* there.

The distributions of some notably disjunct species are plotted on the direct ordination to determine if they have specific ranges of soil pH and moisture which might help to explain their presence on Prospect Mountain. The disjunct species with narrow distributions on the ordination, reflecting a narrow ecological tolerance, are of greatest interest. Figures 45-47 show the distribution of 18 of these species on the ordination.

No single stand contains all or even a large number of these disjunct species. Although most of the 18 species are found in the drier, more basic upper left part of the ordination, and thus overlap over part of their range, no 2 of them exhibit exactly the same distribution on the ordination. *Carex petricosa* has a wide pH range but a narrow moisture range. *Pedicularis flammea, Salix alaxensis,* and *Oxytropis jordalii* are found at the centre of the moisture gradient in addition to the xeric end.

Androsace chamaejasme (Fig. 48) and *Smelowskia calycina* occur over the entire moisture gradient but reach their peak abundance in the drier, basic stands. Therefore the disjunct species are restricted to, or reach their maximum prominence, in the drier, more basic sites, although no

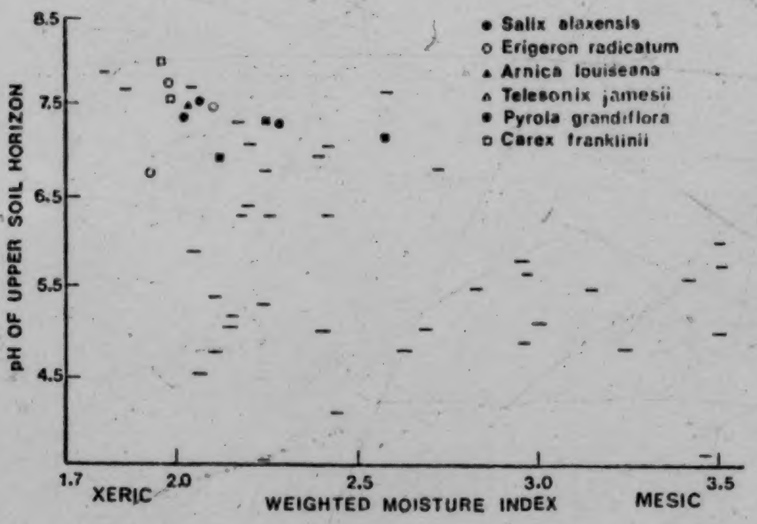


Fig. 45. Distribution of some disjunct species on the direct ordination. Presence only is plotted.

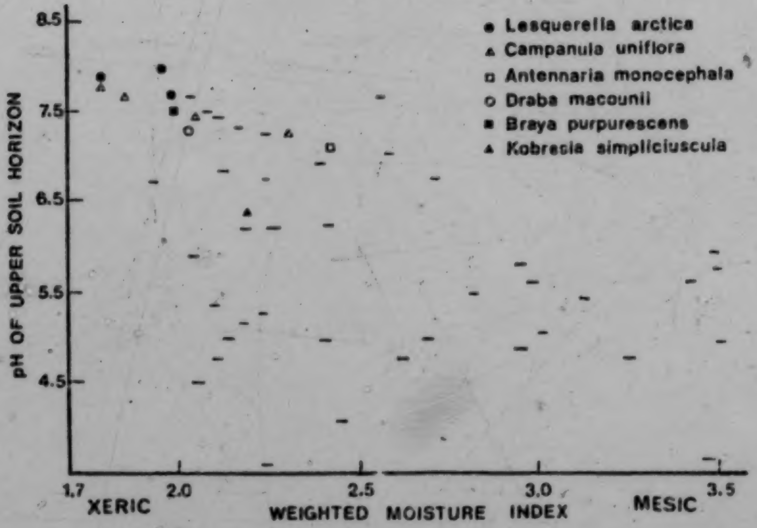


Fig. 46. Distribution of some disjunct species on the direct ordination. Presence only is plotted.

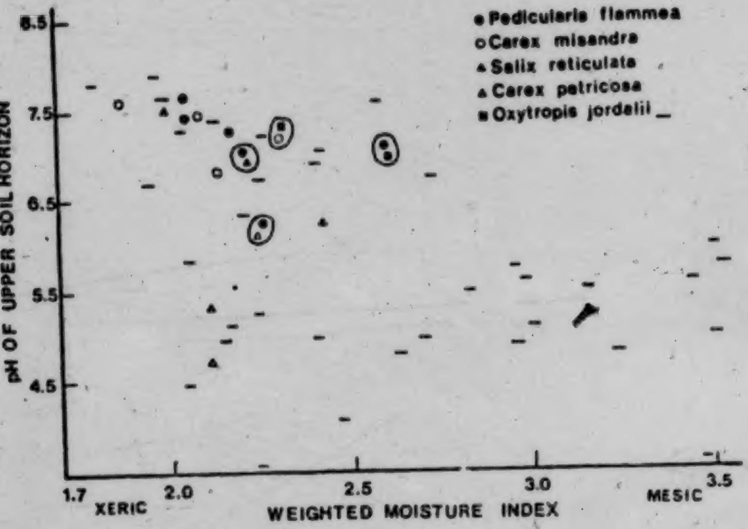


Fig. 47. Distribution of some disjunct species on the direct ordination. Presence only is plotted.

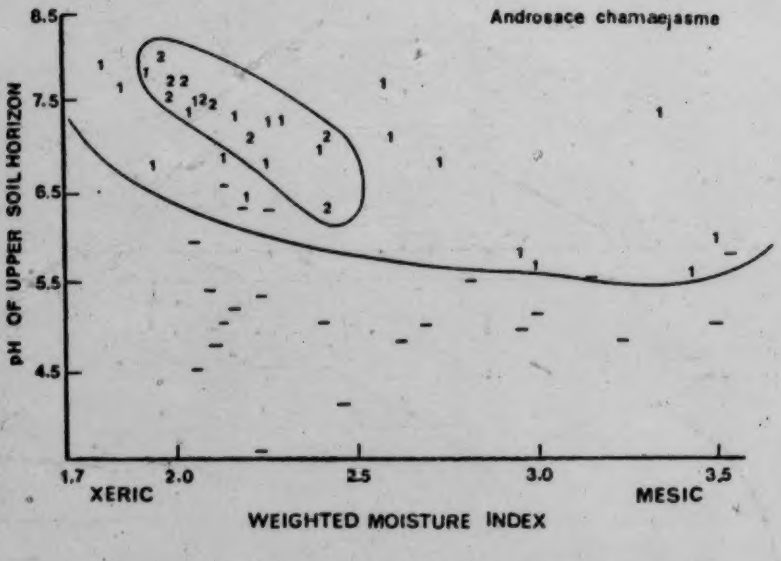


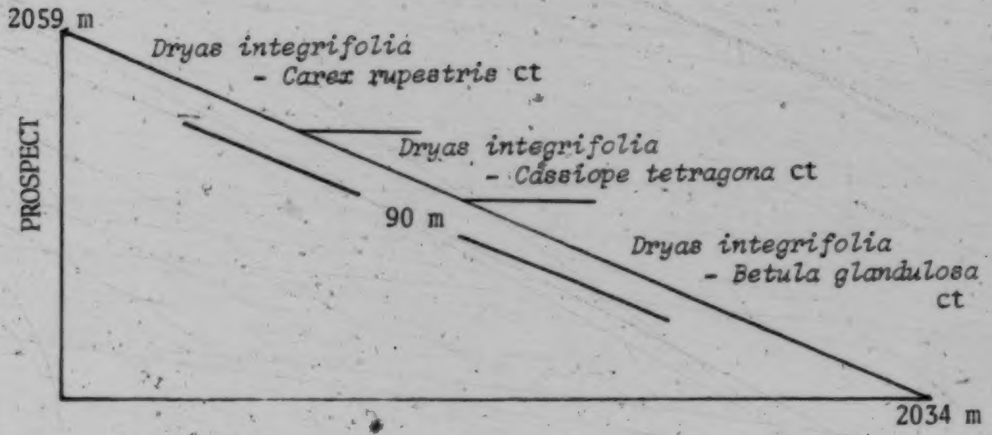
Fig. 48. Distribution of *Androsace chamaejasme* coded PV's on the direct ordination. For PV code see page 29.

specific stand is favoured.

Transects

Comparing equivalent transects is one method of comparing the interrelationships and distribution of ct's on the landscape in different study areas. On Prospect two transects were sampled. One traversed a series of *Dryas integrifolia*-dominated communities and the other followed a snowmelt gradient. Similar transects are described for Bald Hills by Kuchar (1975). On Signal, however, a single transect was run over the entire mountain from N to S (Hrapko 1970). Segments of this extensive transect can be examined which correspond to those on Bald Hills and Prospect.

On Prospect the first transect crosses three main *Dryas integrifolia*-dominated ct's with an increase in elevation on a NW slope: *Dryas integrifolia* - *Betula glandulosa*, *Dryas integrifolia* - *Cassiope tetragona*, and *Dryas integrifolia* - *Carex rupestris*. The Bald Hills transect crosses only one ct, *Dryas octopetala* - lichen, and there is little elevational change. As the Rock Tundra communities on Prospect and Bald Hills have been shown to be physiognomically equivalent only, it is not surprising that there is little correspondence at the transect level. On Signal it is possible to delineate a small transect traversing mainly Rock Tundra communities on an elevational gradient on the N slope. This transect does not have as great an elevational change over its length as the Prospect transect (10 cf. 25 m) and starts at a higher elevation (2190 m ASL cf. 2034 m ASL). These two transects are compared in Figure 49. The Signal transect originates in the *Cassiope*


2059 m
PROSPECT
Dryas integrifolia
- Carex rupestris ct
Dryas integrifolia
- Cassiope tetragona ct
90 m
Dryas integrifolia
- Betula glandulosa
ct
2034 m

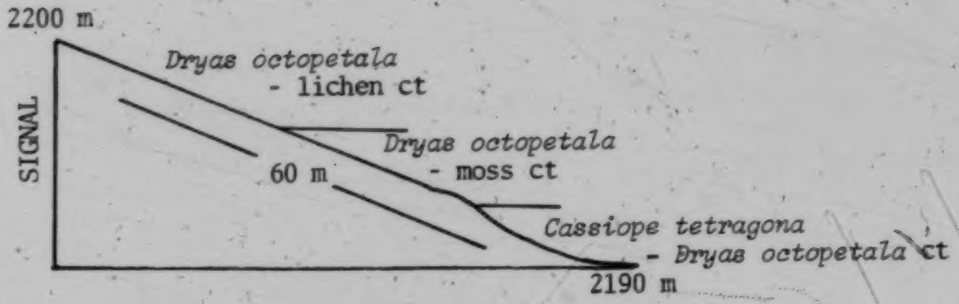

2200 m
SIGNAL
Dryas octopetala
- lichen ct
Dryas octopetala
- moss ct
60 m
Cassiope tetragona
- Dryas octopetala ct
2190 m

Fig. 49. Comparison of *Dryas*-dominated transects on Prospect and Signal Mountain.

tetragona - *Dryas octopetala* ct, crosses the *Dryas octopetala* - moss ct, and ends in the *Dryas octopetala* - lichen ct. The upper two ct's in the Signal and Prospect transects are physiognomically equivalent (see Table 24, page 144), but very different floristically. Below these Rock Tundra communities on Signal is Heath Tundra cf. Shrub Tundra on Prospect. The distribution of the lower two ct's on the Signal transect is greatly influenced by microtopography as well as elevation. The two ct's often intergrade with the *Dryas octopetala* - moss community on the more exposed sites and the *Cassiope tetragona* - *Dryas octopetala* ct in depressional areas (J.Hrapko pers. comm.). The complete mountain transect for Signal shows that Heath Tundra occurs commonly and often dominates from 2190 m down to 2090 m ASL. On Prospect Shrub Tundra covers the zone between the origin of this transect and treeline.

The transect along a snowmelt gradient on Prospect (Fig. 50) originates in *Dryas integrifolia* - *Hedysarum alpinum* Meadow Tundra, crosses *Phyllodoce glanduliflora*- and *Cassiope tetragona*-dominated Heath Tundra communities, and terminates in *Dryas integrifolia* - *Oxytropis podocarpa* Rock Tundra. Although the meadow is in the bottom of the depression, the snowpack against the walls of the depression melts later and therefore the heath communities are released later. On Bald Hills a similar transect originates in a *Carex nigricans* snowbed community, crosses *Luetkea pectinata*-, *Phyllodoce glanduliflora*- and *Cassiope tetragona*-dominated Heath Tundra communities, and ends in a *Dryas octopetala*-lichen Rock Tundra community. On Signal a transect out of a nivation hollow crosses *Carex nigricans*, *Salix arctica* - *Antennaria lanata*, *Cassiope tetragona* - *Dryas octopetala* and finally *Dryas octopetala* - moss communities.

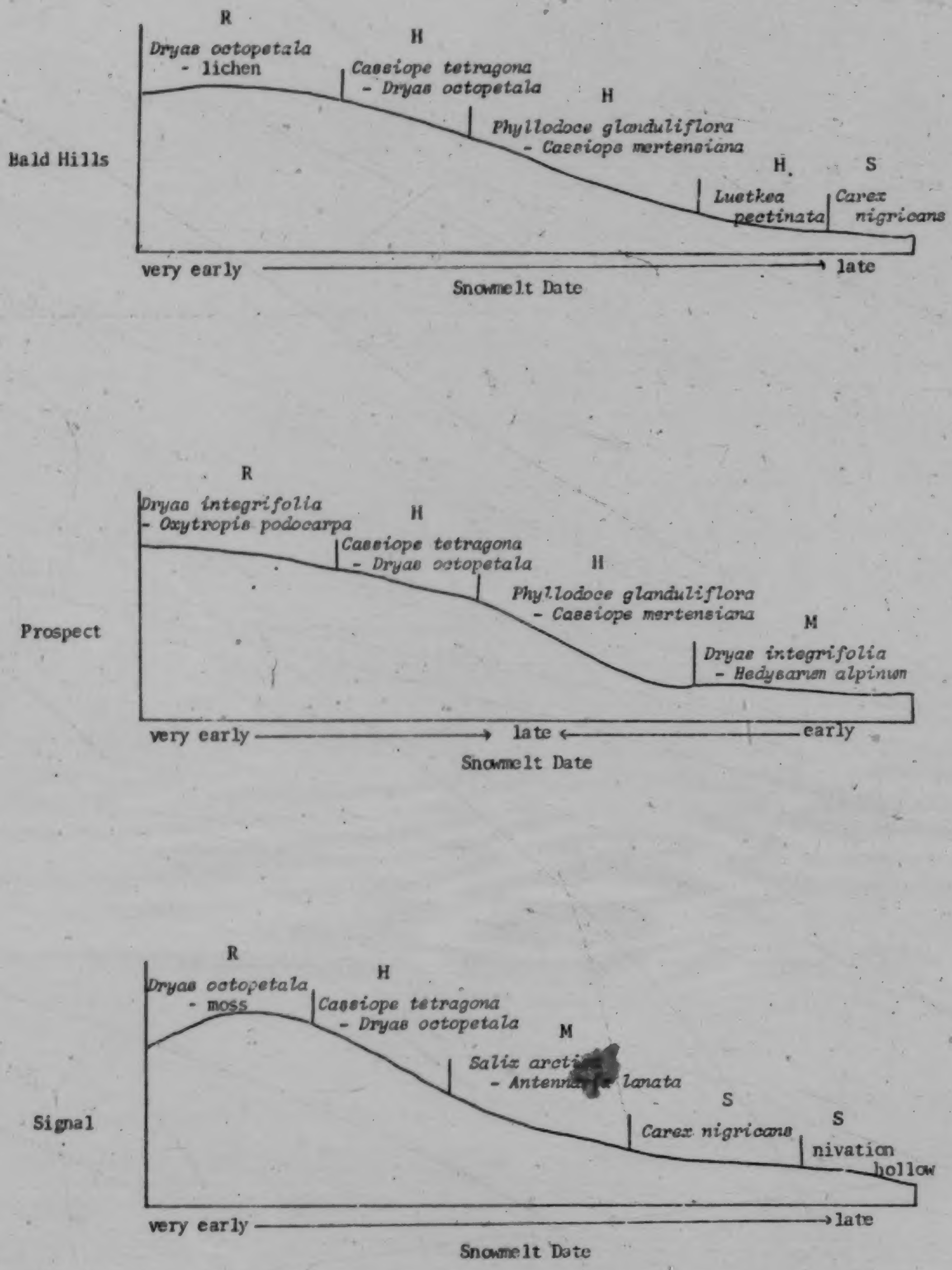

R
Dryas octopetala
- lichen
H
Cassiope tetragona
- Dryas octopetala
H
Phyllodoce glanduliflora
- Cassiope mertensiana
H
Luetkea
pectinata
S
Carex
nigricans
Bald Hills
very early
late
Snowmelt Date
R
Dryas integrifolia
- Oxytropis podocarpa
H
Cassiope tetragona
- Dryas octopetala
H
Phyllodoce glanduliflora
- Cassiope mertensiana
M
Dryas integrifolia
- Hedysarum alpinum
Prospect
very early
late
early
Snowmelt Date
R
Dryas octopetala
- moss
H
Cassiope tetragona
- Dryas octopetala
M
Salix arcti[illegible]
- Antenna[illegible] lanata
S
Carex nigricans
S
nivation
hollow
Signal
very early
late
Snowmelt Date

Fig. 50. Comparison of snowmelt coenoclines from transects surveyed on Prospect, Signal and Bald Hills. Tundra groups are Rock (R), Heath (H), Meadow (M) and Snowbed (S).

The three transects are similar in many ways, with the greatest difference expressed in the Snowbed communities. In terms of relative snow release date, communities released later than Heath Tundra are not represented in the Prospect transect. These areas contain *Carex nigricans* and *Luetkea pectinata* communities on Bald Hills, and *Carex nigricans* and *Salix arctica - Antennaria lanata* communities on Signal. Areas released later than the heath communities on Prospect are usually occupied by the *Salix arctica - Salix nivalis* ct. This ct is found in deep bowl-shaped depressions surrounded by Rock Tundra or Shrub Tundra and there are no characteristic coenoclines corresponding to snow release date associated with these snowbeds.

Heath Tundra components are similar for the three transects. Although the *Phyllodoce glanduliflora - Cassiope mertensiana* ct does not occur on this selected segment of the Signal transect, it does occur infrequently on the snowmelt coenocline there. In all cases the *Cassiope tetragona - Dryas octopetala* ct grades into an earlier-released Rock Tundra community.

The *Dryas integrifolia - Hedysarum alpinum* meadow at the base of the snow accumulation hollow on Prospect has no equivalent on either Signal or Bald Hills. The *Salix arctica - Antennaria* ct is unique to the Signal transect and ecologically equivalent to the *Luetkea pectinata* ct on the Bald Hills transect. *Antennaria lanata* and *Salix arctica* are both significant components of the Heath communities on Bald Hills. *Antennaria lanata* was not sampled on the Prospect transect.

Soils

The soil characteristics for the three areas are compared in Table 25. Prospect soils are more basic than those of the Maligne study areas, with pH's ranging from 5.6 to 8.1 cf. 3.6 to 5.9 for Bald Hills and 4.5 to 6.5 for Signal. Mean pH values further emphasize this difference; Prospect soils average 7.2, Signal 4.9 and Bald Hills 5.5. The pH difference is a result of the difference in parent materials - limestone colluvium on Prospect, shale and conglomerate glacial till and bedrock on Bald Hills, and sandstone and conglomerate bedrock and glacial till on Signal.

Regosolic soils are common to all three areas. Gleysols and Humic Gleysols, described for the wettest locations on Signal and Bald Hills, were not encountered on Prospect. Dystric and Sombric Brunisols, found on Bald Hills and Signal respectively, are acid and not found on Prospect. Eutric and Melanic Brunisols, more basic in nature, are found on Prospect and Signal, but not on Bald Hills.

Mean nitrate concentrations are low and similar for all three study areas. There is more variation in phosphorus concentration, with Prospect soils at the lower end of the scale, having the narrowest range and the lowest mean concentration (3.9 ppm). Bald Hills soils have considerably higher phosphorus concentrations than either of the other two areas, with a mean concentration of 16 ppm. Potassium totals could not be compared as available K was measured for the Maligne study areas and exchangeable K for Prospect.

Available moisture values were not calculated for the Bald Hills soils; Prospect and Signal soils have similar available moisture ranges.

Table 25. Comparison of some characteristics of the soils of Prospect, Bald Hills (Kuchar 1975), and Signal (Hrapko 1970, Hrapko and La Roi 1978). Means and ranges are for all soil samples analyzed for each area.

Characteristic	Prospect	Bald Hills	Signal
Main Parent Material	limestone colluvium	glacial till bedrock shales and conglomerates	bedrock glacial till sandstone and conglomerates
Soil Great Groups	Regosol Humic Regosol Eutric Brunisol Melanic Brunisol	Regosol Gleysol Humic Gleysol Dystric Brunisol	Regosol Gleysol Humic Gleysol Sombric Brunisol Eutric Brunisol Melanic Brunisol
pH (in water)			
range	5.6 - 8.1	3.6 - 5.9	4.5 - 6.5
mean	7.2	4.9	5.5
Nitrate (ppm soil)			
range	0 - 10	0 - 7	0 - 21
mean	1.2	1.6	5.5
Phosphorus (ppm soil)			
range	0 - 15	1 - 77	0 - 21
mean	3.9	16	4.7
Available Moisture (mb) (% O.D. <2 mm)			
range	6 - 48	—	4 - 53
mean	16.3		19.6

Meteorological Observations

Some difficulties arise in attempting to compare meteorological observations from the three areas (Table 26). Prospect data are for 1976 only, and there are no comparable data from Signal or Bald Hills for that year. In general Signal data are also for a single year, 1967, which was abnormally warm and dry (Hrapko 1970). Harter (pers. comm.) has calculated summer precipitation 'normals' for the Signal alpine based on the relationship between the precipitation totals for Signal and Jasper townsite for a 3-year period (1973 - 1975) applied to the 30-year precipitation normals for the Jasper townsite. These are provided for comparison, as an estimate of the amount of precipitation usually received on Signal. Bald Hills data are the means for a 3-year period (1968-1970).

The most significant differences are between the summer precipitation totals for the three sites. Even allowing for yearly fluctuations, Prospect clearly receives much more precipitation in July and August than either of the Maligne sites. Comparison of the 1976 Prospect precipitation totals with long-term records from the nearby Grave Flats Lookout (Table 16, page 125) indicates that this was not a year of abnormally high precipitation.

The mean, mean maximum and mean minimum daily temperatures for July and August on Prospect are intermediate between those of Signal and Bald Hills. The warm, dry weather on Signal in 1967 is reflected in the higher temperatures recorded there for all three categories.

The abnormally warmer and drier 1967 weather on Signal is reflected in the higher VPD's there. The mean VPD's for Prospect and Bald Hills

Table 26. Comparison of July and August meteorological observations for Prospect (1976), Bald Hills (1968-70, Kuchar 1975), and Signal (1967, Hrapko 1970; calculated normals, Harter pers. comm.).

	Prospect (1976)	Bald Hills (1968-70)	Signal (1967)	Signal (calc. norm.)
Precipitation (mm)				
July	75	63	42	62
August	140	80	9	63
Total	215	143	51	125
Temperature (^{o}C)				
mean				
July	8.0	7.3	8.9	
August	7.4	6.9	11.7	—
mean maximum				
July	12.0	10.3	13.3	
August	10.9	10.4	17.2	—
mean minimum				
July	3.9	3.7	4.4	
August	3.9	3.4	7.2	—
Vapour Pressure Deficit (mb)				
mean				
July	3.8	3.0	5.0	
August	2.2	3.1	10.0	—
absolute maximum	14	17	22	
Mean Wind Speed (km/hr)				
July	12.6	6.9	9.1	
August	12.1	6.6	9.8	—

are similar. The maximum VPD measured on Prospect in 1976 (14 mb), however, is lower than the maxima from either Signal (22 mb) or Bald Hills (17 mb).

Mean monthly wind speeds are higher on Prospect. Bald Hills has the lowest mean wind speeds about half the velocity of those on Prospect.

Winter meteorological data are not available for the three study areas, however a visual comparison of the snowpack present at these sites on May 18, 1976 showed the snow in the alpine on Prospect to be restricted to depressional areas, while the alpine areas of both Signal and Bald Hills were almost completely covered with snow.

DISCUSSION

The vegetation and flora of an area can be said to be products of environmental and historical factors. In characterizing the vegetation and flora of Prospect Mountain, and in comparing them to those of Signal Mountain and Bald Hills, climatic, edaphic and historical factors are considered. In order to fully discuss these factors they must be treated both separately and as an integrated whole.

Climatic Factors

Several climatic factors have been suggested as factors controlling the distribution of alpine vegetation in different geographic locations. Bliss (1969) found wind to be central in controlling vegetation patterns in the alpine of New Zealand, snow to be most important in the Olympic Mountains of Washington, and atmospheric moisture in the Presidential Range of New Hampshire. In the Alberta Rocky Mountains, Beder (1967), Hrapko (1970), Broad (1973) and Kuchar (1975) have found snow cover and snow release date to be the primary factors, while Trottier (1972) suggests that the distribution of plant associations at Highwood Pass is controlled by wind exposure, snow cover, temperature and soil moisture.

The major difference in the meteorological observations made at Prospect, Signal and Bald Hills was for precipitation, with Prospect receiving significantly larger amounts during the summer (Table 26, page 171). Powell and MacIver (1976) also recognise this trend, reporting higher summer precipitation values for the foothills area surrounding Prospect which decrease steadily towards the Jasper townsite and the Maligne Range. Increased precipitation levels are reported, however, for sites west of the Jasper townsite. On Prospect the very steep slopes and abundant coarse colluvial material promote rapid drainage. Therefore, the effects of higher summer rainfall on the alpine vegetation are not readily detectable. Indeed the alpine vegetation of Prospect seems more, not less, xerophytic than that of the Maligne Range. A measure of field soil moisture levels would be more indicative of the vegetation's moisture regime than a simple tabulation of summer precipitation.

As noted earlier, snow cover has been singled out as the primary controlling factor in plant community distributions in many Alberta sites. Unfortunately there are no quantitative comparative data on the amount and duration of snow for Prospect, Signal and Bald Hills. A visual comparison of spring snowpack for the 3 areas made on May 18, 1976 showed Prospect to have the least amount of snow remaining in the alpine on that date. This may be due, however, to a lower winter snowfall, higher winter winds, or a difference in exposure or a combination of these factors. Effects of the difference in snowpack can be noted, though. Snowbeds are few and restricted in size on Prospect and the relative paucity of Snowbed Tundra ct's as compared to the Maligne study areas, particularly Bald Hills, may be a result of this.

Wind can also have a profound effect on alpine vegetation, both directly and through its effect on snow distribution (Wilson 1959, Bliss 1960 and 1969). Average wind speeds for July and August on Prospect were higher than those on Signal and Bald Hills (Table 26, page 171). The high wind speeds around the Mountain Park area are well known to the local inhabitants. Roberts (1966) states that for Cadomin, 8 km NE of Prospect, the strongest winds usually occur from November to January, but that heavy winds may come at any time, and winds averaging 72 - 80 km/hr (45 - 50 mi/hr) may blow for days. That these strong winter winds affect the vegetation has been illustrated by Wells *et al.* (1976) who state that in the winter of 1975-76 extensive forest blowdown was reported in the foothills east of Jasper, which would correspond to the Mountain Park area, while only isolated trees were blown over in Jasper Park itself. Higher wind speeds might also decrease snow cover in exposed alpine sites, creating a harsher environment for the plants and restricting the distribution of plant communities requiring snow cover protection. On Prospect, microtopography and its interactions with wind and snow appear to be very important as there is increased plant cover in even the shallowest depressions, and the lusher plant communities are found in only the most protected areas.

The combined effects of strong winter winds, which would remove and redistribute snow, and the rapid drainage loss of meltwater due to topography and soil parent material, may counteract the high summer precipitation to produce a physiologically dry environment for the alpine vegetation on Prospect Mountain.

Edaphic Factors

The alpine soils of Prospect Mountain exhibit many of the generalized characters described for a 'typical' alpine soil, such as high concentrations of organic matter near the surface, granular structure, and low clay content (Retzer 1965, Sneddon *et al.* 1972, Knapik *et al.* 1973), large amounts of stone and gravel, and excessive drainage (Retzer 1974). They differ in having generally sandy loam textures as opposed to the more common silt loam.

Regosolic soils are dominant in the alpine on Prospect with Melanic Brunisols found only in association with heath-dominated plant cover. Wells *et al.* (1977) have found Melanic Brunisols to be dominant or codominant with Regosols on calcareous, medium-textured colluvial material in the alpine tundra subzone of Banff and Jasper National Parks in Alberta. The very steep slopes over much of the study area on Prospect inhibit profile development and contribute to the predominance of Regosolic soils there.

The low nutrient levels (N, P, K) recorded for the Prospect soils are within the range found for other alpine soils in Alberta (Knapik *et al.* 1973, Hrapko 1973, Kuchar 1975). Therefore it can be concluded that the alpine soils on Prospect, though weakly developed, are typical of those previously described for the Alberta Rocky Mountains.

Major (1951) stated that vegetation is not a function of soil nor soil of vegetation, rather both are functions of the ecosystem, and therefore correlations of vegetation with soil properties may be meaningless. Parent material may be more meaningful as it is independent of the ecosystem properties that determine soils and vegetation for an area. In the comparison of soils from Prospect, Signal and Bald Hills the major edaphic difference measured was pH (Table 25, page 169). This pH difference is mainly a reflection of the difference in parent material, limestone on Prospect, sandstone and conglomerates on Signal, and shales and conglomerates on Bald Hills.

The effect of differences in parent material, particularly calcareous and acidic ones, on the vegetation has been examined in a number of studies. Mooney *et al.* (1962) found sandstone sites to have a warmer microclimate than dolomite habitats at equivalent altitudes in the White

Mountains of California, and that shrub species extended to higher altitudes on the sandstone and trees to higher altitudes on the dolomite. Bamberg and Major (1968), however, found soil temperatures in limestone-derived soil to be significantly higher than those in soils derived from igneous rocks. Whittaker and Niering (1968) compared the vegetation on limestone to that on acid parent materials in the Sanata Catalina Mountains in California. They found that vegetation on limestone was characterized by a reduction in plant stature and community structure towards the lower strata, and that there was elevational displacement of species populations in both directions. A variety of high-mountain communities on limestone and dolomite were found to be varyingly different from those on acid soil, e.g. often more open, and usually more xeric in physiognomy and flora.

Bird (1974a), in a comparison of calcareous and acidic alpine areas in the Yukon and Northwest Territories, found the calcareous alpine areas to have higher species richness – 154 vascular species as compared to 64 for otherwise comparable acidic alpine sites. Ninety-five of the species were restricted to calcareous soils but only 11 to acidic soils in this area. This does not necessarily imply obligate calcicoly for these species, though. In their studies of the vegetation associated with calcareous parent materials in Montana, Bamberg and Major (1968) found that only 0.3% of the flora could be classified as calcicolous for the Montana alpine zone, and that several of the species changed their substrate preference further south. They attributed the lack of calcicoly in the Rocky Mountains to the widespread presence of beds of calcareous rocks as opposed to isolated blocks, and low summer rainfall which reduces the leaching of all alpine soils. Simpson (1938) stressed the importance of interspecific competition in the determination of calcicoly and the need to separate direct soil effects from competition effects. A plant seemingly confined to one soil type is generally able to grow on others in the absence of competition (Salisbury 1920).

Also involved in the comparison of vegetation on calcareous and acidic substrates is the concept of "climatic compensation" (Whittaker 1960). A soil under one set of climatic conditions may provide a plant environment similar to another soil under a different set of conditions. Therefore a species may grow in physically different but biologically equivalent (*sensu* Cajander 1926) habitats in different parts of its range. In particular, taxa at the edge of their range often occur on non-regional substrates, e.g. species widespread over most of their range may be restricted to calcareous sites at their distributional limits. Pigott and Walters (1954) have concluded that rare or disjunct plants can occur in a given area where competition is reduced due to an unusual soil parent material. Gankin and Major (1964) have summarized numerous examples of the presence of endemic or disjunct plants on non-regional soils in England. Whittaker (1954) also suggests that relict species or paleoendemics are more likely to survive on, and are therefore characteristic of, soils high in Ca^{++} or Mg^{++}, such as those derived from serpentine, limestone or dolomite. For example, the disjunct and endemic species of the Gaspé Peninsula, which have been suggested as biological evidence for a refugium there, occur on non--regional ferromagnesium or calcareous rocks (Fernald 1925, Morriset 1971). Physiological data alone cannot explain their presence there as some species are present on both the serpentine and limestone rocks.

Any discussion of the flora and vegetation on calcareous as compared to acidic parent material must take all these factors into consideration.

Flora of Prospect Mountain

The total number of vascular species reported for Prospect, Bald Hills and Signal are very similar at 191, 197 and 151 respectively, and are of the same magnitude as totals published for other Rocky Mountain alpine areas. Although a richer alpine flora has been found to be associated with calcareous soils in some places, e.g. Yukon and Northwest Territories (Bird 1974b), the relative richness of habitats is probably just as significant in determining the richness of flora. Wide variations in parent material and moisture regime within a study area make possible a more diverse flora and vegetation.

In terms of species richness, the four most important families on Prospect are Compositae, Graminae, Cruciferae and Cyperaceae, which are similar to the most important families in the Maligne study areas (Table 18, page 128). These results conform to those of Packer (1974b), who found that for a sample of worldwide alpine floras the most species--rich families were Compositae, Cyperaceae, Graminae, Scrophulariaceae and Rosaceae.

There are, however, a few notable differences in the relative important of vascular families between Prospect and the Maligne Range. Leguminous species are more important numerically and ecologically on Prospect. This may be due to substrate differences, as Salisbury (1920) found the native flora of calcareous soils in England to contain a high proportion of legumes. Bamberg and Major (1968) describe an alpine meadow community from the calcareous Big Snowy Mountains in Montana unusually rich in legumes. Some of the legumes found on Prospect are most often found on calcareous soils over their ranges, e.g. *Astragalus aboriginum*.

Prospect is also deficient in graminoids; there are fewer species and they have a lower cover as compared to the Maligne Range. Only the *Elymus innovatus* - *Mertensia paniculata* ct is dominated by a graminoid species. In contrast, graminoids are particularly widespread in the Bald Hills, contributing 5 of the 10 highest presence species found there. Alpine communities dominated by members of the Cyperaceae are common elsewhere in the Rocky Mountains. For example, *Kobresia bellardii* (Beder 1967, Trottier 1972, Crack 1977) and *Carex nardina* (Bryant and Scheinberg 1970) communities are found on dry windswept ridges. It is difficult to say why these xerophytic, sedge-dominated communities are not prevalent on Prospect. The calcareous nature of the soil is probably not a significant factor in the reduced graminoid richness, as grasses are notably well equipped to live in dry, calcareous soils, such as are often encountered in prairie situations. Some of the graminoid deficiency could be explained by the lack of extensive mesic and snowbed habitats on Prospect, which would reduce the number of *Juncus, Luzula, Eriophorum, Carex* and grass species commonly associated with these habitats. For example, the snowbed species *Carex nigricans* and the wetland *Arctagrostis arundunacea* lack suitable habitats on Prospect and are not found in the study area.

The lower number of Ericaceous species on Prospect is almost certainly a direct result of unfavourable edaphic conditions. The genus *Vaccinium*, commonly associated with acidic soils, is absent on

Prospect but has 3 species on Bald Hills and 2 on Signal. *Vaccinium vitis-idaea* acts as a ground cover in some Signal communities, a niche filled by *Salix nivalis* on Prospect. *Kalmia polifolia*, most often associated with acidic soils, is also absent on Prospect.

Therefore most differences in the species richness of vascular plant families are a result of edaphic differences between Prospect and the Maligne Range. In some cases the absence or reduced extent of some habitats reduces the number of species in families commonly associated with that habitat.

The alpine flora of Prospect shows the greatest similarity to those of Ram Mountain and Wilcox Pass (Table 17, page 127). Ram Mountain, also a calcareous Front Range mountain, has also been proposed as a nunatak (Williams and Bayrock 1966) and therefore its high floristic similarity is to be expected. Although Wilcox Pass is well within the Main Ranges, it also has a calcareous substrate which might explain its high degree of similarity. However, Highwood Pass and Snow Creek, which also have calcareous substrates within their study areas, do not display as high a floristic similarity. It is possible that in these two cases latitudinal differences overcome edaphic similarities. Wilcox Pass does deserve closer phytogeographical examination, though, with its high floristic similarity to the suspected refugial sites of Prospect and Ram Mountain, and the presence there of such disjunct species as *Pedicularis flammea* and *Braya purpurescens* (Crack 1977).

Phytogeographical Considerations

In comparing the phytogeography of the 3 study areas, Prospect's flora was found to have a higher proportion of North American arctic-alpine and low-elevation, especially North American low-elevation, species, and to have fewer Amphi-Beringian species. The Maligne study area floras have a slightly higher proportion of circumpolar arctic-alpine, Amphi-Beringian and widespread Cordilleran species, i.e. widely dispersed species which would be expected to inhabit newly opened areas after glacial retreat. The Prospect data are in direct contrast to those of Bird (1974b) who, in his comparison of glaciated and unglaciated calcareous alpine areas in Yukon and Northwest Territories, found unglaciated areas to have fewer low-elevation species, and more North American arctic-alpine and Amphi-Beringian species. Comparisons by the same author of unglaciated calcareous and glaciated silicate alpine areas revealed the same trend.

The largest difference in distributional types between the Prospect and Maligne study areas was in the number of disjunct species. The distribution disjunctions exhibited by these species may be the result of historical factors or a reflection of habitat disjunction, or both.

The distributions of such species as *Androsace chamaejasme* (Fig. 15, page 46), *Campanula uniflora* (Fig. 16, page 46), *Kobresia simpliciuscula*, *Carex franklinii* and *C. petricosa*, which have all been described as inhabiting primarily calcareous substrates (Porsild 1973, Hultén 1968), are composed in part or entirely of narrow disjunctions and are probably the result of habitat disjunctions. *Kobresia simpliciuscula* occurs as disjunct populations on calcareous moraines in England, a distribution

Pigott and Walters (1954) attribute to post-glacial restriction by growth of trees. It has been suggested that *Campanula uniflora* survived in refugia in Scandinavia (Dahl 1955, Gjaerevoll 1963) and Iceland (Steindorsson 1963). In the Alberta Rocky Mountains, however, *Campanula uniflora* is scattered throughout the mountains and not clearly associated with suspected refugial areas. Further work on the distribution of this species in Alberta might shed some light on its migrational history.

Pyrola grandiflora is also scattered in the mountains but has a disjunct population in boreal NE Alberta, which suggests possible habitat disjunction. *Papaver kluanensis* is widespread in the arctic but is restricted to isolated, high mountain peaks in the Rocky Mountains, producing a disjunct distribution.

The distributions of the remaining 14 disjunct species are better explained as the result of historical rather than habitat factors, and are therefore of far greater phytogeographical significance. Packer and Vitt (1974) have discussed the historical implications of the disjunct populations of *Braya purpurescens, Carex misandra, Pedicularis flammea, Telesonix jamesii* and *Smelowskia calycina*, and have concluded that these populations are best explained by persistence in an unglaciated area. Some of these species have been found in suspected refugia in other areas as well. In Scandinavia Dahl (1946) regards *B. purpurescens* as a typical "tundra refugee", a species which survived the glaciations in refugia with tundra vegetation. Dahl (1946) and Gjaerevoll (1963) have also found *P. flammea* and *C. misandra* associated with possible refugial areas in Scandinavia. Ryvarden (1974) has found

P. flammea to have a low reproductive capacity which may account for its restricted distribution. Therefore if this species was associated with past nunataks, it may not have spread extensively since then and would be located close to these nunatak sites. *S. calycina* has been found on a present-day nunatak in the Yukon, growing on high scree slopes which have probably never been glaciated (D. Murray pers. comm.).

Oxytropis jordalii is found in isolated populations in the mountains of Alaska, Yukon and Northwest Territories, and in the Mountain Park area (Fig. 21, page 48). On Prospect *O. jordalii* is found in a single ct, the *Dryas integrifolia - Hedysarum alpinum* ct, in a number of locations.

Salix alaxensis is a widespread arctic willow and collections at Prospect and in the Nordegg area appear to be disjunctions, but may simply represent the southern limit for this species. On Prospect *S. alaxensis* is a gnarled, sprawling shrub, rarely exceeding 0.5 m in height as compared to the 2 - 4 m tree found on river terraces in the arctic. It plays an important ecological role, especially on scree slopes, where it often provides stability and an anchor for the small *Dryas* mats which form the main base of the plant cover. In areas with substantial subsurface drainage *S. alaxensis* becomes a significant component of the *Dryas integrifolia - Hedysarum alpinum* ct.

Salix reticulata is common in the arctic and in the mountains south to Pine Pass, British Columbia. A disjunct population has been found at Mountain Park where it is mixed with the more southerly species *S. nivalis* (G. Argus pers. comm.). *S. reticulata* has been found on present-day nunataks in the Kaskawulsh Glacier in SW Yukon, although these are not areas of persistence (D. Murray pers. comm.). On Prospect it is found in combination with other *Salix* species in moist Shrub Tundra communities.

Lesquerella arctica is primarily arctic in distribution but there are a few disjunct populations in the Northwest Territories and Alberta, the latter at Mountain Park, Wilmore Wilderness, Kananaskis, Ram Mountain and the Bighorn Mountains near Nordegg (Packer unpubl.). On Prospect this species is found occasionally in the *Dryas integrifolia* - - *Carex rupestris* ct.

Arnica louiseana is common in Alaska but is more scattered further south in the Rocky Mountains and the Gulf of St. Lawrence (Fig. 18, page 46). In Alberta populations have been reported from Lake Louise, Banff townsite, Bald Hills, Crowsnest Pass, Waterton Park and Prospect (Packer unpubl.). On Prospect it is restricted to a single N-facing slope covered with the *Dryas integrifolia* - *Oxytropis podocarpa* ct. This species has a number of poorly understood subspecies which, on further examination, might yield valuable information on its persistence in the Rocky Mountains during periods of glaciation.

Antennaria monocephala has a mainly arctic distribution but has disjunct Alberta populations at Mountain Park, Bald Hills, Whistler Mountain, Wilcox Pass and Waterton Park (Packer unpubl.). On Prospect it is very rare; only one specimen was collected, from a *Cassiope tetragona*-dominated hollow.

Rumex alpestris, *Draba macounii* and *Arnica alpina* ssp. *attenuata* appear to have disjunct populations at Prospect, but taxonomic ambiguities complicate the interpretation of the species distributions and further work is required before these species should be considered valid disjuncts. *R. alpestris* has been included in the taxon

R. acetosa (Hitchcock and Cronquist 1973), treated as a subspecies of *R. acetosa* (Hultén 1968), and as a species in its own right (Moss 1959), and therefore its distribution is not clear. Subspecific designations are often ignored in the reporting and mapping of *Arnica alpina*; therefore it is difficult to say if the Mountain Park population of *A. alpina* ssp. *attenuata* is as disjunct as the maps of Hultén (1968) indicate. Previous taxonomic confusion in the genus *Draba* make it difficult to interpret earlier records of this genus and therefore *Draba macounii* should be considered to be a disjunct only tentatively.

Erigeron radicatus is a rare endemic known only from a few locations, including Prospect Mountain. It was first collected by Drummond around 1840 near Jasper Lakes but no plants have been collected in the area since. Recent collections have been made at Prospect, Ram Mountain and nearby Shunda Mountain, and in the Saskatchewan part of the Cypress Hills. On Prospect *E. radicatus* may be locally abundant on dry, exposed, rocky slopes. The Alberta distribution of this species in suspected refugial areas (Packer 1977) suggests its survival on nunataks and its extinction over the rest of its range during Pleistocene glaciation.

The presence of most of these final 14 disjunct species on Prospect, therefore, is best explained by survival *in situ* in a glacial refugium. Habitat disjunctions, especially edaphic ones, do not satisfactorily explain the disjunctions. Before dismissing edaphic disjunction in all cases, however, the concept of climatic compensation must be recalled. These disjunct species are at the extreme limits of their distribution in most cases, and although they may be found on a number of substrates over the majority of their range, it is conceivable that they may become more restricted at these limits, i.e. become calcicoles. Seemingly suitable calcareous alpine sites are, however, not as uncommon as the species themselves.

Alternative explanations to that of a single isolated refugium can be suggested for the large number of arctic disjuncts. First, many of these disjunctions occur between northern British Columbia and the Mountain Park area in Alberta, a rugged mountainous interval which has been poorly collected. More comprehensive coverage of this intervening area, in particular the Front Range, may reveal the presence of some of these arctic species. This raises the question as to whether the Mountain Park populations of these arctic species represent the southern limit of survival or the southern edge of reinvasion by these species since glacial retreat. Many of these arctic disjuncts are found in the same community on Prospect, i.e. the *Dryas integrifolia* - - *Carex rupestris* ct. Polunin (1948) reports the presence of these same species, *Braya purpurescens, Carex misandra, Pedicularis flammea* and *Lesquerella arctica* in a similar community dominated by *D. integrifolia* and *C. rupestris* in the arctic. The environmental suitability of the Rocky Mountain Front Ranges for *D. integrifolia* and *D. integrifolia*--dominated communities would explain the restriction of these species to the Front Ranges. Other arctic species, which do not have notably disjunct distributions, such as *Saxifraga tricuspidata* and *Dryas integrifolia* itself, also reach their southern limits in the Front Ranges in the Mountain Park - Nordegg area.

Secondly, it is possible that a series of glacial refugia existed in the Front Ranges north of Prospect during the Wisconsin glaciation.

The climatic and geographic factors which would have promoted the creation of an ice-free area near Mountain Park could also have operated in a similar manner over the entire length of the Front Ranges. The two ideas of a more or less continuous distribution of the arctic species along the Front Ranges, and a series of glacial refuges there, are not mutually exclusive. A discontinuous line of survival centers would aid in post-glacial dispersal of these species to adjacent areas in the environmentally suitable Front Ranges.

However, not all of the disjuncts on Prospect are arctic species of this type. The presence of *Telesonix jamesii*, which has a primarily southern distribution, and *Smelowskia calycina*, which has a bimodal distribution north and south of Prospect, reinforces the hypothesis of existence of a glacial refugium here. The co-occurrence of so many species which are largely absent from surrounding areas adds further weight to the refugial explanation for their presence (Packer and Vitt 1974).

These proposed refugial species show very restricted distributions in the Alberta Rockies, although widespread in other parts of their ranges, demonstrating poor dispersal ability for these southern populations. A small population which had survived in a glacial refugium might have become depleted of genetic variability and therefore less able to adapt and to spread (Stebbins 1942). The very nature of the present Alberta distribution of these species and the lack of post-glacial dispersal suggests survival in small populations. Isolation may also permit morphological differentiation but this is not readily observable in the Prospect plant populations. Pike (1978), studying the more rapidly evolving butterflies, has found a morphologically distinct population of the alpine butterfly *Bolaria improba* restricted to Prospect Mountain.

The recognized refugial species are widespread on Prospect, occurring in a number of habitats. This is not inconsistent with the idea of survival in a refugium. Although nunataks have been characterized as forbidding, barren, rocky islands, D. Murray (pers. comm.) has studied present-day nunataks in SW Yukon which support a number of different habitats and communities, despite the severe environmental conditions.

Few of the refugial species on Prospect are important ecologically, and most are rare. *Salix alaxensis* is a notable exception and plays an important ecological role in 2 ct's, the *Dryas integrifolia* - *Salix alaxensis* (islands) ct and the *Dryas integrifolia* - *Hedysarum alpinum* ct (*S. alaxensis* st). It does not replace another species found in these communities elsewhere. *Dryas* islands are not uncommon, but nowhere else has the combination of these with *Salix*, or any other low shrub, been described. Since the *Dryas integrifolia* - *Hedysarum alpinum* ct has not been previously described, *S. alaxensis* cannot be considered to be replacing another species in it. *Carex misandra* is widespread in the *Dryas integrifolia* - *Carex rupestris* ct both on Prospect and over its extensive arctic range. No refugial species can be said to be occupying a niche in a Prospect community that is occupied by another species in glaciated areas. Therefore the refugial species do not greatly influence the community composition and vegetation patterns. They serve only to enrich the flora to a small degree.

Vegetation of Prospect Mountain

The alpine vegetation on Prospect is dominated by *Dryas integrifolia* Rock Tundra. Of the 6 ct's in this group, the *Dryas - Carex rupestris* ct has the greatest areal extent. Shrub Tundra, dominated by *Betula glandulosa* and *Salix* species, forms a discontinuous zone of variable width between the Rock Tundra and subalpine zone. Heath Tundra and Snowbed Tundra are restricted to small, isolated, snow accumulation hollows. Meadow Tundra is also limited in extent and lush Herb Meadows are very rare. *Dryas* Meadows, which are more common, are intermediate in composition and habitat between the dry Rock Tundra and the lush Herb Meadows.

Based on the comparison of the vegetation in general and ct's in particular from Prospect, Signal and Bald Hills (see RESULTS, page 144) a number of conclusions can be drawn. The ct's of the Heath Tundra and Snowbed Tundra Groups from the 3 areas show the greatest similarity although both groups have a very restricted distribution on Prospect. On Signal and Bald Hills the Heath Tundra covers large areas of the lower N-facing alpine slopes and continues into the subalpine zone among the krummholz islands. This is certainly not the case on Prospect where Shrub Tundra communities fulfil this role, and Heath Tundra communities are restricted to bowl-shaped depressions. The Shrub Tundra Group, which has not been designated as a separate entity for either Signal or Bald Hills, has limited similarity to ct's in the Maligne Range; only the *Salix arctica* and *S. barrattiana*-dominated communities have floristic equivalents. Meadow Tundra is less important on Prospect than in the Maligne study areas and lacks a 'binding species' such as was noted for the other 2 areas – *Salix arctica* on Signal and *Artemisia norvegica* on Bald Hills.

Transect studies reinforced these conclusions. Comparable transects over patterned ground on N-facing slopes on Signal and Prospect show the replacement of Heath Tundra by Shrub Tundra on Prospect over an altitudinal gradient. Transects along snowmelt gradients show similar relationships between snow release date and Rock Tundra and Heath Tundra communities in the 3 areas. However, the Prospect Mountain transect lacked a true snowbed community such as the *Carex nigricans* and *Luetkea* communities of the Maligne Range.

Previous ecological studies make it possible to compare the Prospect ct's with those from many areas in the Alberta Rocky Mountains. Study areas used for comparison of most ct's are Snow Creek (Beder 1967), Highwood Pass (Trottier 1972), Bow Creek (Broad 1973), Sunshine (Knapik *et al.* 1973), Ram Mountain (Johnson 1973), Wilcox Pass (Crack 1977), Signal Mountain (Hrapko 1970) and Bald Hills (Kuchar 1975).

Discussion so far has been of ct's, distinct plant assemblages described from specific areas. With a knowledge of alpine vegetation from a larger geographical area, syntaxonomically formalized plant associations similar in habitat, physiognomy and species composition can be determined. Ogilvie (1967) proposed 10 alpine plant associations for the Alberta Rocky Mountains which were later revised to 13 (1976). Six and possibly 7 of the Prospect ct's can be assigned to one of the latter 13 associations.

The *Salix barrattiana - Trollius albiflorus* ct belongs to the *Salix barrattiana* association of Ogilvie, which was also found at

Bald Hills, Wilcox Pass, Snow Creek, Highwood Pass, Bow Summit, and Sunshine, but with variable composition. The *Cassiope tetragona* - - *Dryas octopetala* and *Phyllodoce glanduliflora* - *Cassiope mertensiana* ct's belong to the *Cassiope tetragona* and *Phyllodoce glanduliflora* associations, respectively. Both associations are widespread in the Alberta Rockies and have been described from Signal, Bald Hills, Snow Creek, Highwood Pass, Bow Summit and Sunshine. The *Salix arctica* - - *Salix nivalis* ct of Prospect, with further examination, might be assigned to the *Salix nivalis* - *Salix arctica* association. Similar ct's were found on Signal, Bald Hills, Snow Creek, Highwood Pass, Wilcox Pass and Sunshine, although species composition varied greatly. The *Elymus innovatus* - *Mertensia paniculata* ct belongs to the *Elymus innovatus* association reported from Snow Creek. The *Artemisia norvegica* - *Aquilegia flavescens* ct on Prospect closely resembles the seepage variant of the *Elymus* association described by Ogilvie (1976).

The *Dryas integrifolia* - *Betula glandulosa* ct on Prospect is a possible candidate for the *Betula glandulosa* association, however it might be better described as a variant as *Dryas integrifolia*, which is codominant with *Betula* in the Prospect ct, is not listed as a member of the *Betula* association of Ogilvie. A *Betula* - *Dryas* Shrub Tundra community similar to that on Prospect has been found in the alpine zone of Nahanni National Park, Northwest Territories, where it covers significant areas in an equivalent position just above treeline (S. Talbot pers. comm.).

The rest of the ct's on Prospect do not conform to any of the associations proposed by Ogilvie (1976). Alpine assemblages which are common in the other study areas and notably absent on Prospect include the *Carex nigricans* association, the *Dryas hookeriana (octopetala)* - - *Oxytropis podocarpa* association, and the *Kobresia myosuroides (bellardii)* association. Both *Dryas octopetala* and *Kobresia bellardii* are present on Prospect, but they do not clearly dominate any communities there. The *Dryas octopetala* ct's of the *Dryas octopetala* - *Oxytropis podocarpa* association have physiognomic equivalents in the *Dryas integrifolia*-dominated communities from Prospect, but the difference in dominant species is an important one and should not be ignored. As well, even with the dominant *Dryas* species removed there is little correlation between the associated species of *D. octopetala* and *D. integrifolia*. They belong to separate associations. The *Carex nigricans* ct, which is so notably absent on Prospect, has been described for Signal, Bald Hills, Highwood Pass, Snow Creek and Bow Summit.

Only 2 ct's not dominated by *Dryas integrifolia* are not in one of the associations described by Ogilvie. The *Salix arctica* - *Hedysarum alpinum* ct resembles the *Salix arctica*-dominated communities on Signal, Bald Hills, Wilcox Pass and Highwood Pass. The *Salix* spp. - *Cassiope tetragona* ct has no equivalent ct described elsewhere in the Alberta Rocky Mountains. However, similar plant assemblages have been found in the alpine zone of Nahanni National Park, Northwest Territories (S. Talbot pers. comm.).

The rest of the Prospect ct's are dominated by *Dryas integrifolia*. Of all the alpine study areas in the Alberta Rockies, only Ram Mountain is dominated by *D. integrifolia* as opposed to *D. octopetala*, and might possess similar *D. integrifolia*-dominated communities. However, the *D. integrifolia*-dominated communities on Ram are evidently neither as rich nor as diverse as those on Prospect. Spotted tundra of

D. integrifolia, possibly equivalent to the *Dryas integrifolia - Salix alaxensis* ct on Prospect, and a *Dryas - Kobresia* ct somewhat similar to the Prospect *Kobresia* st of the *Dryas integrifolia - Oxytropis podocarpa* ct, have been described from Ram. No other Prospect communities have equivalents there.

The rest of the *Dryas integrifolia*-dominated communities, therefore, either have no equivalent community described in the literature examined, or the closest equivalent is north or south of the Alberta Rockies. The *Dryas integrifolia - Hedysarum alpinum* Meadow Tundra community and the *Dryas integrifolia - Oxytropis podocarpa* and *Dryas integrifolia - Salix arctica* Rock Tundra communities have had no equivalent described for any location.

Arctic communities similar to the *Dryas integrifolia - Cassiope tetragona* ct of Prospect have been described from Devon Island, Northwest Territories (Muc and Bliss 1977), the SW Mackenzie, Northwest Territories (Raup 1947), and eastern Greenland (Elkington 1965), although all are more species-poor than the Prospect community.

The *Dryas integrifolia - Carex rupestris* ct, which covers the largest area on Prospect, has the most interesting geographical relationships. The closest floristic equivalent is the *Dryas integrifolia - - Carex rupestris* community widespread in the Big Snowy Range of Montana (Bamberg and Major 1968). Important species associated with the *Dryas* and *Carex* in Montana are *Polygonum viviparum, Androsace chamaejasme* and *Saxifraga oppositifolia* which are all significant in the Prospect ct. The ct in Montana forms spotted tundra as on Prospect and combines with *Arctostaphylos uva-ursi* in a manner similar to that of the *A. uva-ursi* st described for Prospect. A *Dryas integrifolia* -

- *Carex rupestris* ct is widespread in the alpine of Nahanni National Park (S. Talbot pers. comm.). It is rich in lichens, especially *Cetraria* spp., as is the Prospect ct. A *Dryas integrifolia - Carex rupestris* ct rich in lichens has also been described for western Greenland by Gelting (1955) which has the same associated species as on Prospect, *Polygonum viviparum, Carex nardina, Pedicularis lanata, Silene acaulis* and *Saxifraga oppositifolia*.

A depauperate form of the *Dryas integrifolia - Carex rupestris* ct covers large areas in the North American arctic. Polunin (1948) has described such communities from the eastern arctic islands of Devon, Baffin, Ellesmere and Dorset and from northern Quebec. Barrett (1972), Svoboda (1974) and Muc and Bliss (1977) have also described similar communities on Devon island, with high lichen and bryophyte cover. In the arctic a core assemblage of *Dryas integrifolia, Carex rupestris, Polygonum viviparum, Saxifraga oppositifolia,* and often *Carex nardina* and *C. misandra,* is augmented by such species as *Cassiope tetragona, Salix arctica, S. reticulata, Pedicularis lanata, Saxifraga tricuspidata* and *Campanula uniflora* over its range.

The *Dryas integrifolia - Carex rupestris* ct on Prospect can be desribed as consisting of the basic arctic *Dryas - Carex* ct to which numerous alpine species have been added. Since a number of the disjunct refugial species are found in this ct on Prospect Mountain, the relative distributions of *Dryas integrifolia, Dryas octopetala* and vegetation dominated by each, and therefore species associated with each, are of particular interest.

Dryas octopetala is an arctic-alpine species with a discontinuous circumpolar distribution. It is widespread in the Eurasian arctic but absent from the North American High Arctic (Hultén 1968). In North America it is found over much of the western Cordillera and has been considered to be the most important plant species in the Canadian Rockies (Kuchar 1975). *Dryas integrifolia*, in contrast, is a widespread North American arctic-alpine and northern boreal species and has been considered the most characteristic species of the Polar Semi-desert (Svoboda 1974). The ranges of the two species overlap in many places and, when they occur in close proximity, hybrids may be found (Hultén 1959, Elkington 1965, Bamberg and Major 1968, Crack 1977).

Although distribution maps of *D. integrifolia* and *D. octopetala* in Alberta show both species to be common in the mountains north of 51° latitude (Crack 1977, Packer unpubl.), patterns of dominance show definite geographical separation. One *Dryas* species is always dominant in areas of co-occurrence. On Prospect, where both are found, *D. integrifolia* is clearly dominant and *D. octopetala* is restricted to specific mesic habitats. Conversely, at Wilcox Pass *D. octopetala* dominates while *D. integrifolia* is found only in localized patches (Crack 1977).

Differentiation of the ecological requirements of the two species is not always clear. Kuchar (1975) states that *D. octopetala* throughout its range occupies sites which have gravelly, poorly developed soils low in nutrients and water, high wind exposure, lack of winter snow cover and extreme diurnal temperatures. The habitat of *D. integrifolia* has been characterized as including sites with low available soil nutrients and moisture, and high soil surface temperatures (Svoboda 1974). At one extreme it has been suggested that *D. octopetala* is restricted to acidic soils and *D. integrifolia* to calcareous ones (Kuchar 1975, See 1978), and at the other that their ecological requirements are the same (Elkington 1965, Bamberg and Major 1968). In Norway *D. octopetala* is almost exclusively calcicolous (Coombe and White 1951, Gjaerevoll 1963). Although found on acidic soils it reaches its greatest dominance and luxuriance on calcareous soils. In Montana Bamberg and Major (1968) use *D. octopetala* as an indicator species for calcareous soils. At Wilcox Pass in Jasper National Park *D. octopetala* dominates the primarily calcareous substrate, although *D. integrifolia* is also encountered there (Crack 1977). In the southern Alberta Rockies, at and beyond the limits of the range of *D. integrifolia*, *D. octopetala* is the dominant species in most calcareous alpine sites. Therefore the degree of calcicoly of *D. octopetala* depends on its geographic location and the competing species.

It now appears that alpine areas dominated by *D. integrifolia* in Alberta are restricted to specific locations in the generally drier Front Ranges above 51° latitude. Svoboda (1974) describes morphological and Hartgerink (1975) physiological adaptations of *D. integrifolia* which enable it to grow in sterile calcareous substrates that are relatively warm and dry. It is possible that in the Alberta Rocky Mountains, where the ranges of the two *Dryas* species overlap, *D. integrifolia* can outcompete *D. octopetala* in the drier calcareous Front Ranges. Further south, where *D. integrifolia* does not occur, *D. octopetala* occupies these sites exclusively. In the Yukon, See (1978) has also noted that *D. integrifolia* is more prevalent in the mountains east of the Continental Divide. A more comprehensive study is required, not only of the relative distribution of these species, but also the distribution of areas dominated by each.

However this is an ecological interpretation of the present distribution, and historical factors must also be considered. Hulten (1959) suggested that *D. integrifolia* once covered areas in the Rocky Mountains south of its present distribution. Since the retreat of the continental and cordilleran ice sheets, *D. integrifolia* has re-occupied the northern part of the area which was once covered by Wisconsin glaciation (Porsild 1947). Of phytogeographical interest therefore is a disjunct population of *D. integrifolia* which occurs in the Big Snowy Mountains of Montana (Bamberg and Major 1968). This is not simply a case of habitat disjunction, as numerous suitable calcareous locations in the Front and Main Ranges exist between this population and the more numerous Alberta populations. The Montana area is of particular interest as the *D. integrifolia*-dominated communities there showed the greatest similarity to the Prospect *D. integrifolia*-dominated communities. Indeed there is a great deal of similarity between the floras of the two areas as an index of similarity of 42% for the two study areas has been calculated, despite the large difference in latitude. Assuming a wider distribution of *D. integrifolia* in the past, it is possible that the *D. integrifolia* in the Big Snowy Mountains, which have never been glaciated (Bamberg and Major 1968), has persisted there as a remnant of the earlier wider distribution.

The existence of both *D. integrifolia* and *D. octopetala* in unglaciated areas of Alaska and Yukon has allowed the development of geographically distinct races or subspecies (Hultén 1959). Although this phenomenon is better known and documented for *D. octopetala*, the examination of *D. integrifolia* populations in isolated areas such as the Big Snowy Mountains and the southernmost Alberta sites might reveal subspecific variation, and aid in the determination of whether these populations are products of persistence or represent the present limits of reinvasion of this species. Environmental conditions which are restricting the distribution of *D. integrifolia* now might also be restricting the distribution of other arctic species associated with it.

Integration

The various environmental and historical factors which influence the vegetation and flora of Prospect interact on several levels to produce its contemporary vegetation. Therefore, having examined the various factors separately, they must now be treated together.

The comparison of Prospect and the two Maligne study areas showed that edaphic factors, in particular parent material and pH, are of greatest importance in differentiating the vegetation and flora of the two areas. The effects of summer climatic differences are obscurred by this edaphic difference. Although Prospect receives more summer precipitation, its steep topography and coarse limestone colluvium promote rapid drainage and create a dry environment for the alpine plants. Strong winter winds at Prospect and their effect on snow distribution must also be important, but snow accumulation and release could not be precisely compared for the three areas

Ordination methods were used to try to determine the environmental gradients which might be causing the separation of ct's within and among study areas. The results were disappointing. It is possible that the complexity of environmental controls for stands from the three areas could not be clearly described using only two axes, and ordinations using more axes might have been more successful. Snow release date would be an obvious choice for an additional axis, but the necessary data were not available so it could not be constructed. The ordinations, both direct and indirect, did show soil pH to be important in separating communities from the two major study areas. However, within each study area relative snow cover and release are probably more important in determining ct distribution than edaphic factors. Therefore similar ct's in similar positions on a snowmelt coenocline remained separated on the ordination field due to edaphic differences.

Between the Prospect and Maligne study areas the greatest differences in vegetation result from differences in the dominant, and therefore associated, species. Most of these differences, in turn, are the result of edaphic conditions. For example, *D. integrifolia* outcompetes *D. octopetala* on the calcareous Prospect Mountain, dominating over half of the ct's and contributing greatly to the distinctive nature of the vegetation there. Legumes, which are notably more species-rich on calcareous sites (Salisbury 1920), are both numerically and ecologically important on Prospect. Differences in the relative extent and richness of heath communities might also be related to edaphic differences, as many members of the heath family are acidophilous.

The combined environmental factors of high winds, low snowfall, steep topography and coarse, calcareous parent material on Prospect severely limit the extent of snowbed habitats and preclude the occurrence of true wetland habitats, thus reducing the diversity of ct's and species which are normally associated with these habitats. It is still difficult, however, to account for the complete absence of *Carex nigricans*. Snowbeds, although very few and very small, are present and seem to provide suitable habitats but *Carex nigricans* does not inhabit them. Closer examination of the ecophysiology of this species might reveal answers to this problem.

The Pleistocene history of the Prospect area does not appear to affect the character of the vegetation as a whole, since the refugial species are mostly rare, insignificant ecologically, and account for only 9 - 10% of the flora. History has, however, affected the composition of the flora to some degree and possibly the relative proportions of various phytogeographical distribution types within the flora.

The substrate difference between Prospect and the Maligne study areas makes comparison of the effects of glacial history on the vegetation very difficult. Bird (1974a) encountered similar problems in establishing the existence of a refugium in the Plains of Abraham area, Northwest Territories, as the nearby glaciated Mt. Clark has an exposed bedrock of substantially different type. It would be best if the edaphic 'treatment' could be constant in future studies in both regions.

In Alberta the nature of the cordilleran and continental ice sheet advance and coalescence confines most suspected refugia to the generally calcareous Front Ranges. The more heavily glaciated Main Ranges are composed of a variety of bedrock types, including calcareous ones, but the differences in climate, especially precipitation, would likely complicate a comparative study with the Front Ranges. Therefore perhaps the best comparison would be of geographically close, glaciated and unglaciated areas, on similar substrates within the Front Ranges.

SUMMARY AND CONCLUSIONS

1. Prospect Mountain is located in the Front Ranges of the Rocky Mountains of Alberta (52° 55' N; 117° 22' W), 86 km SSW of Edson and 7 km W of the razed mining town of Mountain Park. There is considerable biological and geological evidence that this area was a glacial refugium during the Wisconsin glaciation. The study area includes the alpine zone on Prospect Mountain, defined as the zone above the growth of trees with supranival leaders.

2. The objectives of the study were to characterize, quantitatively and qualitatively, the alpine vascular flora and vegetation of Prospect Mountain, in a suspected glacial refugium, and to compare them with those of the heavily glaciated Signal Mountain and Bald Hills, and to determine the relative roles of climate, soils and glacial history in accounting for the observed differences.

3. Prospect Mountain is composed of 4 near-parallel ridges of Lower Cretaceous sandstone and shale, stretching to the NE and separated by steep-sided valleys. Most slopes are covered with coarse limestone colluvium derived from the peak of Paleozoic limestone and dolomite. Patterned ground is common, especially wind- and slope-oriented vegetation stripes, small solifluction and turf-banked terraces and spotted tundra.

4. The soils are mainly derived from the limestone colluvium. Profiles are generally shallow and poorly developed, with sandy loam textures. Regosols dominate most of the study area and Melanic Brunisols are

localized and associated with heath-dominated vegetation. Soil pH ranges from 5.6 to 8.1, averaging 7.2 for the 29 profiles exposed. Available nitrate, ammonium and phosphorus, and exchangeable potassium concentrations are all low, with slightly higher concentrations in the surface horizons. Available moisture values (moisture held between 1/3 and 15 bars) of the <2 mm fractions are low for most samples and range from 6 to 48% on an oven-dry basis.

5. Meteorological observations were made at one main station in June, July and August of 1976. June had the coolest mean temperature of 4 °C, while July and August were similar at 8.0 and 7.4 °C respectively. A total of 287 mm of precipitation fell during the study period: 72 mm in June, 75 mm in July and 140 mm in August. Vapour pressure deficits ranged from 0 to 10 mb with a mean of 2.5 mb for the summer. The wind blew almost constantly and mean monthly wind speeds were 14.1 km/hr for June, 12.6 km/hr for July and 12.1 km/hr for August.

6. The alpine vascular flora of Prospect Mountain consists of 191 species in 34 families. The most species-rich families are Compositae, Gramineae, Cruciferae and Cyperaceae. The high-presence species are *Androsace chamaejasme*, *Dryas integrifolia* and *Polygonum viviparum*. The flora was divided into 9 main distribution types; the most species-rich types are circumpolar arctic-alpine (25% of flora), North American arctic-alpine (14%), circumboreal (14%), widespread Cordilleran (13%) and North American low-elevation (13%). Twenty-one species have populations on Prospect which are notably disjunct from their major centers of distribution. The types of disjunct distributions exhibited by these species are described.

7. Using cluster analysis, similarity matrices and field observations, the 31 stands sampled quantitatively on Prospect were classified into 16 community types (ct's) within 5 major groups.

a) Rock Tundra Group — This group covers the largest area and is characterized by extensive bare ground and rock rubble, patterned ground, Regosolic soils and low species richness. All 6 ct's of the group are dominated by *Dryas integrifolia*, and *Polygonum viviparum*, *Carex rupestris*, *Androsace chamaejasme* and *Oxytropis podocarpa* are common. Community types in this group are the *Dryas integrifolia* - *Carex rupestris* ct, the *Dryas integrifolia* - - *Salix alaxensis* (islands) ct, the *Dryas integrifolia* - *Salix arctica* ct, the *Dryas integrifolia* - *Oxytropis podocarpa* ct, the *Dryas integrifolia* - *Cassiope tetragona* ct, and the *Dryas integrifolia* - *Hedysarum mackenzii* ct.

b) Shrub Tundra Group — This group is composed of 2 subgroups: the Shrub Stripe Subgroup, consisting of the *Dryas integrifolia* - - *Betula glandulosa* ct, and the Willow Scrub Subgroup consisting of the *Salix arctica* - *Hedysarum alpinum* ct, the *Salix* spp. - - *Cassiope tetragona* ct, and the *Salix barrattiana* - *Trollius albiflorus* ct. It is a heterogeneous group, characterized by dominant shrub species, mesic habitats, high bryophyte cover and Regosolic soils.

c) Heath Tundra Group — These communities are restricted to small hollows on the S and SE slopes, surrounded by krummholz of *Abies lasiocarpa*. The 2 ct's of this group are characterized by dominant heath species, high plant cover, numerous subalpine species, late snow release and Melanic and Eutric Brunisols. The 2 ct's are the *Cassiope tetragona - Dryas octopetala* ct, at the edges of the hollows in areas of earlier snow release, and the *Phyllodoce glanduliflora - Cassiope mertensiana* ct in areas of later snow release.

d) Snowbed Tundra Group — Snowbeds are small and few in number, and melt out later than the heath hollows. Snowbeds are low in total plant cover, have relatively high lichen cover and Regosols. Only 1 ct, the *Salix arctica - Salix nivalis* ct, is described for this group.

e) Meadow Tundra Group — This heterogeneous group is composed of 2 subgroups, *Dryas* Meadows and Herb Meadows. All ct's have high plant cover with a continuous or discontinuous layer of showy herbs, a good source of water all season, and Regosolic soils, although the profiles may be deep. The *Dryas* Meadow Subgroup has 1 ct, the *Dryas integrifolia - Hedysarum alpinum* ct, which, with its continuous layer of *Dryas* and rich herb assemblage, is intermediate between the Rock Tundra Group and the Herb Meadow Subgroup. The *Elymus innovatus - Mertensia paniculata* ct and *Artemisia norvegica - Aquilegia flavescens* ct of the Herb Meadow Subgroup have very high plant cover and occur in sheltered locations.

8. Two transects were sampled. The first followed an altitudinal gradient over communities dominated by *Dryas integrifolia*. One Shrub Tundra and 2 Rock Tundra ct's were traversed. The lower section of the transect had terraced topography, high moss cover and high shrub cover.

The upper end of the transect had vegetation stripes, lower plant cover, lower species richness, fewer shrubs and slightly higher lichen cover. *Hedysarum alpinum* was found only at the lower end of the transect and *Hedysarum mackenzii* at the upper. The second transect covered 4 distinct ct's along a snowmelt gradient in a large depression. Rock Tundra communities were released first, Meadow Tundra next, and Heath Tundra last. There were no Snowbed Tundra communities. Highest species richness occurred in transition zones, and the lowest in Rock Tundra ct's.

9. In comparing the soils of Prospect with those of Signal and Bald Hills in the Maligne Range, the major measured difference is in soil pH. The pH of the Prospect soils is higher, a reflection of the difference in parent material between the 2 ranges. Soil types, nutrient concentrations, and available moisture were all found to be similar in the 3 study areas.

10. The major difference in meteorological observations taken at Prospect and the Maligne study areas is in precipitation; Prospect has significantly higher total summer precipitation. Comparison with long-term records from nearby Grave Flats indicate that 1976 was not a year of abnormally high rainfall. Average wind speeds for the summer of 1976 on Prospect were higher than those from the Maligne sites in other years. Reports from the literature show that the Prospect area often experiences high wind speeds, especially in winter. No large differences were noted in air temperature or vapour pressure deficit. No quantitative winter meteorological data were available for comparison.

11. Prospect and Signal have a vascular floristic similarity of 58%. Between Prospect and Bald Hills it is 56%, and between Signal and Bald Hills it is 81%. The total number of species recorded in each study area is similar at 191, 197 and 151 for Prospect, Bald Hills and Signal respectively. Although the most important families in the 3 areas are also similar, there are some notable differences. Families which are significantly larger on Prospect include Salicaceae, Leguminosae and Cruciferae (cf. Signal only). Families with the graminoid growth-form, i.e. Gramineae, Cyperaceae and Junaceae, are less important on Prospect, as are Ericaceous species. The alpine flora of Prospect is composed of a higher percentage of North American low-elevation and North American arctic-alpine species, and fewer Amphi-Beringian species. A significantly larger proportion of the Prospect flora is made up of species with disjunct distributions.

12. Cluster analysis was performed on stands from all 3 study areas. Qualitatively based cluster analysis showed the Prospect stands to be compositionally distinct. Of the final 2 clusters formed in the fusion hierarchy, 1 was composed entirely of Prospect stands and the other of Maligne Range stands. The quantitatively based cluster analysis, which weights the species by their abundance, showed most Rock Tundra, Shrub Tundra and Meadow Tundra stands from Prospect to be structurally and compositionally distinct from all Maligne stands at all cluster levels. Similar results were obtained when the two dominant *Dryas* species were removed, demostrating the dissimilarity of the subdominant and associated species in the stands in these 3 vegetation groups. Snowbed Tundra and Heath Tundra communities from the 3 areas were more homogeneous.

13. Communities from the Maligne Range which were equivalent floristically or physiognomically to those of Prospect were designated. Floristic equivalents could be assigned to all Heath Tundra and Snowbed Tundra communities on Prospect. Most Rock Tundra communities, however, are physiognomic equivalents only, while Shrub and Meadow Tundra communities have equivalents of both types. Some Prospect communities have no known equivalents of either type.

14. A comparison of transect studies from the 3 areas illustrates the replacement on Prospect of Heath Tundra by Shrub Tundra on a elevational gradient. Snowmelt transects also showed the lack of a true snowbed community on the Prospect transect; Heath Tundra often occupies the sites with the latest snowmelt.

15. Alpine plant communities from other sites in the Alberta Rocky Mountains were compared to those on Prospect. Prospect was found to possess members of the *Salix barrattiana, Cassiope, Phyllodoce, Elymus, Salix nivalis - Salix arctica* and possibly the *Betula glandulosa* associations, all widespread in the Alberta Rocky Mountains. The *Carex nigricans* and *Kobresia* associations were notably absent on Prospect. *Dryas integrifolia*-dominated communities, especially the *Dryas integrifolia - Carex rupestris* ct, show greatest similarity to communities on the Big Snowy Mountains, E of the Divide in Montana, and to those of the North American arctic.

16. Disjunct species found on Prospect were found to be of 2 types: those whose presence is best explained by habitat disjunction; and those for which a historical explanation is most reasonable. The latter

species, which have possibly survived in a glacial refugium in the area, have major centers of distribution both north and south of Prospect. Refugial species were found to be generally low in cover and to occur in a number of habitats encompassing a large range of soil pH values and soil moisture regimes. Many of the arctic species with disjunct populations on Prospect are found in the *Dryas integrifolia - Carex rupestris* ct, as they are in the arctic. Only *Salix alaxensis* and *Carex misandra* are important ecologically, and no refugial species replaces another species found in the same ct in a heavily glaciated area.

17. Indirect and direct ordination techniques were used to try to determine what environmental factors have contributed to the differentiation of communities between the 2 main study areas. Of all the edaphic and climatic factors plotted, soil pH showed the greatest correlation with community placement on the indirect ordination field, and therefore it was used as an axis in the direct ordination. Plotting the stand groups formed by cluster analysis showed differentiation along the pH gradient of stands with a high degree of compositional and structural similarity. Snow depth and release date are probably more important than soil pH or moisture in determining the placement of Heath and Snowbed Tundra communities on the landscape. No comparable snow data were available to be plotted.

18. Differences in parent material and soil pH have the largest effect in producing differences in vegetation and flora between Prospect and the Maligne Range study areas. The edaphic differences exert a selective influence on the local vascular flora due to the differing environmental requirements and optima of numerous species in the regional

flora. The difference in parent materials affects the relative species richness and ecological importance of some families, notably the Leguminosae and Ericaceae, which affects both the composition of the flora and the vegetation patterns. Edaphic differences between study areas effect changes in the dominant species, mostly due to differences in optimal pH, e.g. *Dryas integrifolia* cf. *D. octopetala*. This difference in dominant species, along with differences in associated species and, therefore, in the communities themselves, accounts for the lack of floristically equivalent communities on some similar habitats on Prospect, Signal and Bald Hills.

19. The greatest measured climatic difference between the 2 main study areas was summer precipitation. However the higher precipitation on Prospect is counteracted by higher wind speeds, steeper slopes, and more rapid drainage which produce a xeric environment for alpine plants. Perhaps the greatest unmeasured climatic effects on the vegetation are from winter wind and snow and their interactions. Higher winter wind speeds on Prospect would remove and redistribute snow creating more exposed sites, accounting for the larger extent of Rock Tundra there. It would permit fewer snowbed habitats and perhaps explains the lower diversity of snowbed communities and species. Similarly, it would create fewer sites suitable for Heath Tundra which is therefore restricted to small hollows. Consequently Shrub Tundra is important on the lower alpine slopes where Heath Tundra might otherwise be expected to dominate.

20. Of the 3 major factors, glacial history has had the smallest influence on the vegetation and flora of Prospect. It accounts for the presence of certain disjunct, refugial species which enrich and differentiate the flora slightly. It may have had an effect on the relative species richness of the phytogeographical categories which make up the floras in the 3 study areas, In general, however, it has had a minimal effect on the vegetation.

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APPENDIX I — List of vascular species found in the alpine zone on Prospect Mountain.

OPHIOGLOSSACEAE
Botrychium lunaria (L.) Sw.

POLYPODIACEAE
Cystopteris fragilis (L.) Bernh.

SELAGINELLACEAE
Selaginella densa Rydb.

EQUISETACEAE
Equisetum arvense L.
Equisetum scirpoides Michx.
Equisetum variegatum Schleich.

PINACEAE
Abies lasiocarpa (Hook.) Nutt.
Juniperus communis L.
Juniperus horizontalis Moench.
Picea engelmannii Parry

GRAMINEAE
Agropyron latiglume (Scribn. & Smith) Rydb.
Agropyron smithii Rydb.
Bromus pumpellianus Scribn.
Calamagrostis purpurascens R.Br.
Deschampsia caespitosa (L.) Beauv.
Elymus innovatus Beal
Festuca baffinensis Polunin
Festuca brachyphylla Shultes
Phleum alpinum L.
Poa alpina L.
Poa arctica R.Br.
Poa cusickii Vasey
Poa pattersonii Vasey
Poa pratensis L.
Poa rupicola Nash
Trisetum spicatum (L.) Richt.

CYPERACEAE
Carex atrosquama Mack.
Carex festivella Mack.
Carex franklinii Boott
Carex misandra R.Br.
Carex nardina Fries
Carex petricosa Dewey
Carex phaeocephala Piper
Carex physocarpa Presl.
Carex raymondii Calder
Carex rupestris All.
Carex scirpiformis Mack.
Carex scirpoidea Michx.
Carex spectabilis Dewey
Kobresia bellardii (All.) Degl.
Kobresia simpliciuscula (Wahlenb.) Mack.

JUNCACEAE
Juncus drummondii E. Meyer
Luzula parviflora (Ehrh.) Desv.
Luzula spicata (L.) DC.

LILIACEAE
Streptopus amplexifolius (L.) DC.
Tofieldia pusilla (Michx.) Pers.
Veratrum eschscholtzii A. Gray
Zygadenus elegans Pursh.

ORCHIDACEAE
Habenaria viridis (L.) R.Br.

SALICACEAE
Salix alaxensis (Anderss.) Coville
Salix arbusculoides Anderss.
Salix arctica Pall.
Salix barrattiana Hook.
Salix drummondiana Barratt
Salix glauca L.
Salix nivalis Hook.
Salix reticulata L.
Salix vestita Pursh.

BETULACEAE
Betula glandulosa Michx.

POLYGONACEAE
Eriogonum androsaceum Benth.
Oxyria digyna (L.) Hill
Polygonum viviparum L.
Rumex alpestris (Scop.) Löve

PORTULACACEAE

Claytonia lanceolata Pursh

CARYOPHYLLACEAE

Cerastium beeringianum Cham. & Schlect.
Lychnis apetala L.
Minuartia austromontana Wolf & Packer
Minuartia rubella (Wahlenb.) J.E. Smith
Minuartia sajanensis Willd.
Silene acaulis L. var *exscapa* (All.) DC.
Stellaria monantha Hultén

RANUNCULACEAE

Aconitum delphinifolium DC.
Anemone drummondii S. Wats.
Anemone multifida Poir.
Anemone parviflora Michx.
Aquilegia flavescens S. Wats.
Delphinium glaucum S. Wats.
Ranunculus eschscholtzii Schlecht.
Thalictrum occidentale A. Gray
Trollius albiflorus (A. Gray) Rydb.

PAPAVERACEAE

Papaver kluanensis D. Löve

CRUCIFERAE

Arabis drummondii A. Gray
Braya humilis (C.A. Mey.) Robins
Braya purpurescens (R.Br.) Bunge
Draba albertina Greene
Draba aurea M. Vahl.
Draba borealis DC.
Draba cana Rydb.
Draba crassifolia Grah.
Draba incerta Payson
Draba lonchocarpa Rydb. var *lonchocarpa*
Draba macounii O.E. Shultz
Draba oligosperma Hook.
Draba paysonii Macbr.
Draba porsildii G.A. Mulligan
Lesquerella arctica (Wormskj.) Wats.
Smelowskia calycina (Stephan) C.A. Mey.

SAXIFRAGACEAE

Mitella nuda L.
Parnassia fimbriata Konig.
Parnassia kotzebuei Cham. & Schlect.
Ribes oxycanthoides L.
Saxifraga adcendens L.
Saxifraga aizoides L.
Saxifraga caespitosa L.
Saxifraga cernua L.
Saxifraga lyallii Engler
Saxifraga oppositifolia L.
Saxifraga tricuspidata Rottb.
Telesonix jamesii (Torr.) Raf.

ROSACEAE

Dryas integrifolia M. Vahl.
Dryas octopetala L.
Fragaria virginiana Duschesne
Potentilla diversifolia Lehm.
Potentilla diversifolia var *multisecta* (S. Wats) Rydb.
Potentilla fruticosa L.
Potentilla gracilis Dougl.
Potentilla nivea L.
Potentilla uniflora Ledeb.
Sibbaldia procumbens L.

LEGUMINOSAE

Astragalus aboriginum Richards
Astragalus alpinus L.
Astragalus occidentalis (S. Wats.) M.E.Jones
Astragalus vexilliflexus Sheld.
Hedysarum alpinum L.
Hedysarum boreale Nutt.
Hedysarum mackenzii Richards
Oxytropis campestris (L.) DC. var *cusickii* (Greene) Barneby
Oxytropis jordalii Pors.
Oxytropis podocarpa A. Gray
Oxytropis splendens Dougl.

ONAGRACEAE

Epilobium angustifolium L.
Epilobium hornmanii Reichenb.
Epilobium latifolium L.

UMBELLIFERAE

Heracleum lanatum Michx.

PYROLACEAE

Monensis uniflora (L.) A. Gray
Pyrola asarifolia Michx.
Pyrola grandiflora Radius

ERICACEAE

Arctostaphylos rubra (Rehder & Wils.) Fern.
Arctostaphylos uva-ursi (L.) Spreng.
Cassiope mertensiana (Bong.) D. Don
Cassiope tetragona (L.) D. Don
Ledum groenlandicum Oeder
Phyllodoce glanduliflora (Hook.) Coville
X Phyllodoce intermedia (Hook.) Camp

PRIMULACEAE

Androsace chamaejasme Host
Androsace septentrionalis L.

GENTIANACEAE

Gentiana prostrata Haenke
Gentianella amarella (L.) Borner
Gentianella propinqua (Richards) J.M.Gillett

HYDROPHYLLACEAE

Phacelia sericea (Graham) A. Gray

BORAGINACEAE

Mertensia paniculata (Ait.) G. Don
Myosotis alpestris Schmidt

SCHROPHULARIACEAE

Castilleja miniata Dougl.
Castilleja occidentalis Torr.
Euphrasia disjuncta Fern. & Wieg.
Pedicularis bracteosa Benth.
Pedicularis capitata Adams
Pedicularis flammea L.
Pedicularis lanata Cham. & Schlect.
Veronica alpina L. var *unalaschensis* C & S

CAPRIFOLIACEAE

Linnaea borealis L.

VALERIANACEAE

Valeriana sitchensis Bong.

CAMPANULACEAE

Campanula lasiocarpa Cham.
Campanula rotundifolia L.
Campanula uniflora L.

COMPOSITAE

Achillea millefolium L.
Antennaria alpina (L.) Gaertn.
Antennaria lanata (Hook.) Greene
Antennaria monocephala DC.
Arnica alpina (L.) Olin
Arnica alpina (L.) Olin ssp *attenuata* (Greene) Maguire
Arnica cordifolia Hook.
Arnica diversifolia Greene
Arnica louiseana Farr
Artemisia norvegica Fries
Aster alpinus L.
Aster sibericus L.
Crepis nana Richards
Erigeron compositus Pursh
Erigeron grandiflorus Hook.
Erigeron humilis Grah.
Erigeron lanatus Hook.
Erigeron peregrinus (Pursh.) Greene
Erigeron radicatus Hook.
Petasites frigidus (L.) Fries var *nivalis* (Greene) Cronq.
Saussurea densa (Hook.) Rydb.
Senecio canus Hook.
Senecio lugens Richards
Senecio triangularis Hook.
Solidago multiradiata Ait.
Taraxacum ceratophorum (Ledeb.) DC.
Taraxacum lyratum (Ledeb.) DC.

APPENDIX II. Similarity matrix for the Prospect Mountain stands

IS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		19	81	89	64	63	61	38	57	56	55	2	.5	3	.2	.3	46	80	47	60	74	65	7	49	.2	12	4	.1	48	3	1
2			17	21	23	8	24	24	7	9	9	0	.2	3	0	0	8	11	8	10	10	9	7	5	0	9	7	0	8	5	0
3				87	53	72	56	35	61	63	51	.2	1	2	.3	.2	55	80	47	57	64	55	7	56	.1	12	6	.1	47	3	.2
4					61	66	66	41	58	57	57	1	2	3	1	1	49	77	50	64	71	61	8	50	.3	14	6	.1	52	4	2
5						43	87	61	38	35	47	.1	.2	3	.1	.2	27	58	42	49	54	52	9	31	.2	16	7	1	41	5	.3
6							44	29	67	64	52	1	2	3	2	2	55	73	51	68	65	70	8	76	2	22	16	.1	62	22	1
7								62	39	35	47	1	1	4	1	1	28	53	43	53	52	48	9	33	.4	17	6	.1	44	5	2
8									28	22	30	3	2	4	8	.4	18	35	37	39	34	45	22	22	7	28	11	2	39	21	19
9										49	74	5	5	6	4	2	40	68	67	62	59	62	13	58	3	44	13	.2	54	18	10
10											40	1	14	15	1	.5	76	58	34	41	47	42	18	78	.4	23	3	.1	35	3	2
11												.4	6	7	3	4	32	62	63	64	58	62	17	47	3	46	13	1	57	14	17
12													7	6	61	6	1	2	2	4	1	4	9	3	4	6	2	4	6	11	12
13														79	5	3	2	5	2	4	3	5	65	4	1	22	1	.1	5	7	11
14															4	3	2	4	2	3	4	5	64	4	1	24	3	.4	5	8	9
15																4	1	3	7	4	2	8	10	3	7	9	2	4	10	12	9
16																	1	2	4	6	2	3	5	1	86	13	7	7	6	10	6
17																		47	29	35	39	34	5	68	.2	8	3	0	30	2	2
18																			50	67	77	73	10	61	2	16	7	.4	55	9	7
19																				64	59	62	13	40	10	38	17	4	66	19	13
20																					68	79	13	57	8	28	23	3	76	26	12
21																						72	10	51	2	18	9	.4	64	9	3
22																							18	60	8	32	21	2	78	37	17
23																								10	8	39	12	5	19	25	30
24																									2	20	3	.1	55	21	7
25																										17	14	8	9	12	6
26																											18	1	34	35	26
27																												11	21	26	1
28																													3	8	.1
29																														41	22
30																															42

APPENDIX III. Annotated list of alpine species found on Prospect, Signal and Bald Hills. For distribution type (DT) see page 37, and for moisture index (MI) see page 31.

	DT	MI
OPHIOGLOSSACEAE		
Botrychium lunaria (L.) Swartz	9	3.0
POLYPODIACEAE		
Cystopteris fragilis (L.) Bernh.	9	1.0
Gymnocarpium dryopteris (L.) Newm.	9	-
Polystichum lonchitis (L.) Roth.	2	-
EQUISETACEAE		
Equisetum arvense L.	9	4.0
Equisetum scirpoides Michx.	9	3.0
Equisetum variegatum Schleich	3	3.5
LYCOPODIACEAE		
Lycopodium alpinum L.	2	3.5
Lycopodium annotinum L.	9	-
Lycopodium clavatum L.	9	-
Lycopodium selago L.	2	3.0
SELAGINELLACEAE		
Selaginella densa Rydb.	4	2.0
PINACEAE		
Abies lasiocarpa (Hook.) Nutt.	4	2.5
Juniperis communis L.	9	2.5
Juniperis horizontalis Moench.	8	2.5
Picea engelmanii Parry	4	2.5
Pinus contorta Loudon var *latifolia* Engelm.	4	-
GRAMINEAE		
Agropyron latiglume (Scribn. & Smith) Rydb.	8	3.0
Agropyron smithii Rydb.	8	4.0
Agrostis variabilis Rydb.	6	3.0
Arctagrostis arundinaceas (Trin.) Beal	3	5.0
Bromus pumpellianus Scribn.	3	3.0
Calamagrostis inexpansa A. Gray	3	3.0
Calamagrostis purpurascens R.Br.	3	2.0
Danthonia intermedia Vasey	8	-
Deschampsia atropurpurea (Wahlenb.) Scheele	9	3.5
Deschampsia caespitosa (L.) Beauv.	9	4.0
Elymus innovatus Beal.	8	3.0
Festuca baffinensis Polunin	1	2.0
Festuca brachyphylla Schultes	2	2.5
Hierochloe alpina R. & S.	2	2.0

	DT	MI
Phleum alpinum L.	2	4.0
Poa alpina L.	2	2.5
Poa arctica R. Br.	2	2.5
Poa cusickii Vasey	6	3.5
Poa interior Rydb.	8	-
Poa lettermanii Vasey	6	-
Poa pattersonii Vasey	7	2.0
Poa pratensis L.	9	4.0
Poa rupicola Nash	4	2.0
Poa scabrella (Thurb.) Benth. ex Vasey	4	-
Trisetum spicatum (L.) Richter	2	2.5

CYPERACEAE

	DT	MI
Carex albonigra Mack.	4	1.0
Carex atrata L.	9	4.0
Carex atrosquama Mack.	4	3.0
Carex bipartita All.	9	-
Carex brevipes Boott	4	-
Carex brunnescens (Pers.) Poir.	9	3.0
Carex eleusinoides Turcz.	3	-
Carex festivella Mack.	8	4.0
Carex franklinii Boott	2	1.5
Carex glacialis Mack.	2	-
Carex haydeniana Olney	6	-
Carex incurviformis Mack.	7	-
Carex macrochaeta C.A. Mey.	3	-
Carex microglochin Wahlenb.	2	4.0
Carex misandra R. Br.	2	2.0
Carex nardina Fries	1	1.5
Carex nigricans C.A. Mey.	4	3.5
Carex paupercula Michx.	9	-
Carex paysonis Clokey	6	-
Carex petricosa Dewey	5	1.5
Carex phaeocephala Piper	4	3.0
Carex pyrenaica Wahlenb.	2	-
Carex raymondii Calder	8	-
Carex rupestris All.	2	1.5
Carex scirpiformis Mack.	6	2.0
Carex scirpoidea Machx.	3	2.5
Carex spectabilis Dewey	3	3.5
Eriophorum polystachion L.	2	-
Eriophorum scheuchzeri Hoppe	2	5.0
Eriophorum viridicarinatum Fern.	8	-
Kobresia bellardii (All.) Degl.	2	2.5
Kobresia simpliciuscula (Wahlenb.) Mack.	2	2.0

	DT	MI
JUNCACEAE		
Juncus biglumis L.	2	2.0
Juncus castaneus Sm.	2	5.0
Juncus drummondii E. Meyer	4	3.5
Juncus mertensianus Bong.	3	-
Luzula arcuata (Wahlenb.) Sw.	3	3.0
Luzula parviflora (Ehrh.) Desv.	9	3.5
Luzula spicata (L.) DC.	2	2.0
Luzula wahlenbergii Rupr.	2	3.5
LILIACEAE		
Streptopus amplexifolius (L.) DC.	9	4.0
Tofieldia pusilla (Michx.) Pers.	2	3.0
Veratrum eschscholtzii A. Gray	4	4.0
Zygadenus elegans Pursh.	8	2.5
ORCHIDACEAE		
Habenaria viridis (L.) R. Br.	9	2.0
SALICACEAE		
Salix alaxensis (Anderss.) Coville	3	3.0
Salix arbusculoides Anderss.	8	-
Salix arctica Pall.	2	2.5
Salix barrattiana Hook.	5	3.5
Salix drummondiana Hook.	5	-
Salix glauca L.	9	-
Salix nivalis Hook.	6	2.5
Salix reticulata L.	2	3.5
Salix vestita Pursh.	8	2.0
BETULACEAE		
Betula glandulosa Michx.	8	2.0
POLYGONACEAE		
Eriogonum androsaceum Benth.	7	1.0
Oxyria digyna (L.) Hill	2	3.0
Polygonum viviparum L.	2	3.0
Rumex alpestris (Scop.) Love	2	4.0
PORTULACACEAE		
Claytonia lanceolata Pursh.	6	4.0
CARYOPHYLLACEAE		
Cerastium beeringianum Cham. & Schlect.	2	2.5
Lychnis apetala L.	2	1.0
Minuartia austromontana Wolf and Packer	7	2.0

	DT	MI
Minuartia obtusiloba (Rydb.) Fern.	3	2.5
Minuartia rubella (Wahlenb.) J.E. Smith	2	1.5
Minuartia sajanensis Willd.	1	2.5
Sagina saginoides (L.) Britt.	2	-
Silene acaulis L.	2	1.5
Stellaria calycantha (Ledeb.) Bong.	9	2.5
Stellaria longipes Goldie	9	2.5
RANUNCULACEAE		
Aconitum delphinifolium DC.	3	3.5
Anemone drummondii S. Wats.	4	2.0
Anemone multifida Poir.	8	4.0
Anemone occidentalis Wats.	6	4.0
Anemone parviflora Michx.	1	2.5
Aquilegia flavescens S.Wats.	6	3.5
Caltha leptosepetala DC.	4	4.0
Delphinium glaucum S. Wats.	8	3.0
Ranunculus eschscholtzii Schlecht.	3	4.0
Ranunculus gelidus Kar. & Kir.	4	1.0
Ranunculus nivalis L.	2	-
Ranunculus pygmaeus Wahlenb.	2	-
Thalictrum occidentale A. Gray	4	4.0
Trollius albiflorus (A. Gray) Rydb.	8	4.0
PAPAVERACEAE		
Papaver kluanensis	2	4.0
CRUCIFERAE		
Arabis drummondii Gray	8	4.0
Arabis lyallii Wats.	6	2.5
Arabis lyrata L.	3	4.0
Braya humilis (C.A. Mey.) Robins	2	1.0
Braya purpurescens (R. Br.) Bunge	2	1.0
Cardamine bellidifolia L.	2	5.0
Cardamine oligosperma Nutt.	3	4.0
Draba albertina Greene	5	4.0
Draba aurea M. Vahl.	1	4.0
Draba borealis DC.	3	3.5
Draba cana Rydb.	9	2.0
Draba crassifolia Grah.	1	3.0
Draba incerta Payson	4	1.5
Draba lonchocarpa Rydb.	4	1.5
Draba macounii O.E. Shultz	5	1.0
Draba nivalis Liljebl.	2	1.0
Draba oligosperma Hook.	4	1.0

	DT	MI
Draba paysonii Macbr.	5	1.0
Draba porsildii G.A. Mulligan	5	2.0
Draba praealta Greene	4	-
Erysium pallasii (Pursh) Fern.	2	-
Lesquerella arctica (Wormskj.) Wats.	1	1.0
Smelowskia calycina (Stephan) C.A. Mey.	2	1.0
CRASSULACEAE		
Sedum lanceolatum Torr.	4	2.5
SAXIFRAGACEAE		
Leptarrhena pyrolifolia (D.Don) R. Br. ex Ser.	5	-
Mitella nuda L.	9	4.0
Parnassia fimbriata Konig.	4	3.5
Parnassia kotzebuei Cham. & Schl.	1	3.5
Ribes oxycanthoides L.	8	-
Saxifraga adscendens L.	4	-
Saxifraga aizoides L.	2	2.5
Saxifraga bronchialis L.	3	1.0
Saxifraga caespitosa L.	2	2.0
Saxifraga cernua L.	2	2.5
Saxifraga lyallii Engl.	5	3.5
Saxifraga occidentalis Wats.	6	-
Saxifraga oppositifolia L.	2	1.0
Saxifraga punctata L.	3	5.0
Saxifraga rhomboidea Greene	6	-
Saxifraga rivularis L.	2	-
Saxifraga tricuspidata Rottb.	1	2.0
Telesonix jamesii (Torr.) Raf.	6	1.0
ROSACEAE		
Dryas integrifolia M. Vahl.	1	2.0
Dryas octopetala L.	2	2.0
Fragaria virginiana Duchesne	8	4.0
Luetkea pectinata (Pursh) Kuntze	4	3.5
Potentilla diversifolia Lehm.	4	3.0
Potentilla diversifolia Lehm. var. *multisecta* (S. Wats.) Rydb.	6	2.5
Potentilla fruticosa L.	9	2.5
Potentilla gracilis Dougl.	8	4.0
Potentilla hyperarctica Malte	2	3.0
Potentilla nivea L.	2	2.0
Potentilla uniflora Ledeb.	3	2.0
Potentilla villosa Pall. ex Pursh	3	-
Rosa acicularis Lindl.	9	-
Rubus idaeus L.	9	-

	DT	MI
Sibbaldia procumbens L.	2	3.5
LEGUMINOSAE		
Astragalus aboriginum Richards	1	1.5
Astragalus alpinus L.	2	2.5
Astragalus occidentalis (S. Wats.) M.E. Jones	8	-
Astragalus vexilliflexus Sheld.	4	2.5
Hedysarum alpinum L.	9	2.5
Hedysarum boreale Nutt.	8	-
Hedysarum mackenzii Richards	1	2.0
Oxytropis campestris (L.) DC.	9	2.0
Oxytropis jordalii Pors.	1	3.0
Oxytropis podocarpa A. Gray	1	1.5
Oxytropis splendens Dougl.	8	-
EMPETRACEAE		
Empetrum nigrum L.	9	2.0
ELEAGNACEAE		
Shepherdia canadensis	8	-
ONAGRACEAE		
Epilobium alpinum L.	2	4.0
Epilobium angustifolium L.	9	3.0
Epilobium clavatum Trel.	6	-
Epilobium hornemanii Reichenb.	2	4.0
Epilobium lactiflorum Hausskn.	2	-
Epilobium latifolium L.	2	2.5
UMBELLIFERAE		
Heracleum lanatum Michx.	8	4.0
PYROLACEAE		
Monensis uniflora (L.) A. Gray	9	3.0
Pyrola asarifolia Michx.	9	3.0
Pyrola grandiflora Radius	2	2.0
Pyrola minor L.	9	-
Pyrola secunda L.	9	4.0
ERICACEAE		
Arctostaphylos rubra (Rehder & Wils.) Fern.	2	2.5
Arctostaphylos uva-ursi (L.) Spreng.	9	2.0
Cassiope mertensiana (Bong.) D. Don	4	3.0
Cassiope tetragona (L.) D. Don	2	2.5
Kalmia polifolia Wang var. *microphylla* (Hook.) Rehd.	6	-

	DT	MI
Ledum groenlandicum Oeder	8	2.5
Phyllodoce glanduliflora Coville	5	3.0
Phyllodoce empetriformis (Smith) D.Don	4	3.5
Vaccinium caespitosum Michx.	8	-
Vaccinium scoparium Leiberg	6	3.0
Vaccinium vitis-idaea L. var. *minus* Lodd.	9	2.0
PRIMULACEAE		
Androsace chamaejasme Host	2	2.5
Androsace septentrionalis L.	9	3.0
CAPRIFOLIACEAE		
Linnaea borealis L.	9	2.5
GENTIANACEAE		
Gentiana glauca Pallas	3	3.0
Gentiana prostrata Haenke var. *americana* Engl.	2	2.5
Gentianella amarella (L.) Borner	9	4.0
Gentianella propinqua (Richards) J.M. Gillett	1	3.0
HYDROPHYLLACEAE		
Phacelia sericea (Graham) A. Gray	6	1.0
BORAGINACEAE		
Mertensia paniculata (Ait.) G. Don	8	3.5
Myosotis alpestris Schmidt	2	2.5
SCROPHULARIACEAE		
Castilleja miniata Dougl.	4	4.0
Castilleja occidentalis Torr.	7	3.5
Castilleja rhexifolia Rydb.	6	4.0
Euphrasia disjuncta Fern. & Wieg.	8	4.0
Pedicularis arctica R. Br.	1	2.0
Pedicularis bracteosa Benth.	6	3.5
Pedicularis capitata Adams	2	2.5
Pedicularis flammea L.	1	3.0
Pedicularis groenlandicum Retz.	8	4.0
Pedicularis lanata Cham & Schlecht	1	1.5
Penstemon ellipticus Coult. & Fish.	7	-
Veronica alpina L. var. *unalaschensis* C. & S.	1	3.5
VALERIANACEAE		
Valeriana sitchensis Bong.	5	4.0

	DT	MI
CAMPANULACEAE		
Campanula lasiocarpa Cham.	3	2.5
Campanula rotundifolia L.	9	2.0
Campanula uniflora L.	1	1.5
COMPOSITAE		
Achillea millefolium L.	9	4.0
Agoseris aurantiaca (Hook.) Greene	4	4.0
Antennaria alpina (L.) Gaertn.	9	2.0
Antennaria lanata (Hook.) Greene	6	3.0
Antennaria monocephala DC.	1	2.0
Antennaria umbrinella Rydb.	8	-
Arnica alpina (L.) Olin	2	2.5
Arnica alpina (L.) Olin ssp. *attenuata* (Greene) Mag.	1	3.0
Arnica cordifolia Hook.	4	4.0
Arnica diversifolia Greene	6	3.5
Arnica latifolia Bong.	4	4.0
Arnica louiseana Farr	1	2.0
Arnica mollis Hook.	6	4.0
Arnica rydbergii Greene	6	4.0
Artemisia michauxiana Bess	4	-
Artemisia norvegica Fries	9	3.5
Aster alpinus L.	2	2.5
Aster sibericus L.	3	3.0
Crepis nana Rich.	2	1.0
Erigeron acris L. var. *debilis* Gray	4	-
Erigeron aureus Greene	6	2.5
Erigeron compositus Pursh	1	2.0
Erigeron grandiflorus Hook.	1	3.5
Erigeron humilis Grah.	1	3.0
Erigeron lanatus Hook.	7	1.0
Erigeron pallens Cronq.	7	-
Erigeron peregrinus (Pursh) Greene	4	3.5
Erigeron radicatus Hook.	7	1.0
Hieracium gracile Hook.	4	4.0
Petasites frigidus (L.) Fries	2	4.5
Saussurea densa (Hook.) Rydb.	7	1.5
Senecio canus Hook.	4	2.0
Senecio cymbalarioides Nutt.	4	-
Senecio freemontii T. & G.	6	-
Senecio lugens Richards	8	3.0
Senecio pauciflorus Pursh	4	3.5
Senecio triangularis Hook.	4	4.0
Solidago multiradiata Ait.	8	2.5
Taraxacum ceratophorum (Ledeb.) DC.	2	2.5
Taraxacum lyratum (Ledeb.) DC.	1	1.5

APPENDIX IV. Mean cover of some additional species along Transects # 1 and #2.

Transect #1

$\bar{x}$ cover	Transect Segment*														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Stellaria longipes	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex misandra	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-
Silene acaulis	-	3	-	-	3	3	+	1	+	+	-	+	-	1	-
Saussurea densa	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+
Solidago multiradiata	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-

* mean of 4 consecutive quadrats (1-4, 5-8, etc.)

Transect #2

$\bar{x}$ cover	Transect Segment*																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20**
Arnica alpina	1	+	+	-	1	-	-	-	+	-	2	1	-	+	-	-	-	-	-	-
Solidago multiradiata	-	1	1	+	-	-	-	-	-	-	-	1	-	+	-	+	+	-	-	-
Potentilla diversifolia	-	1	-	+	4	+	+	-	+	-	+	+	+	+	+	1	-	-	-	-
Carex scirpoidea	-	-	+	+	+	-	-	-	+	-	-	-	-	-	-	+	-	-	+	-
Gentianella propinqua	-	+	+	+	+	-	-	-	-	+	+	+	+	-	-	+	-	-	-	-
Poa alpina	-	+	-	+	+	+	+	+	-	-	+	-	-	+	1	-	+	-	-	+
Androsace chamaejasme	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-
Euphrasia disjuncta	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erigeron humilis	-	-	+	+	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Trisetum spicatum	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Antennaria alpina	-	-	-	+	+	-	-	-	+	1	-	-	+	+	+	-	-	+	-	-
Carex atrosquama	-	-	-	-	+	-	-	-	-	+	+	+	-	-	+	1	-	-	-	-
Poa arctica	-	-	-	-	+	1	-	-	-	-	-	-	+	+	-	-	-	-	-	-
Phleum alpinum	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Carex misandra	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Petasites frigidus	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Veronica alpina	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-
Elymus innovatus	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-
Aster alpinus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
Stellaria longipes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
Pyrola asarifolia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	2	-

* mean of 5 consecutive quadrats (1-5, 6-10, etc.)

** mean of 3 consecutive quadrats (96 - 98)

APPENDIX V. Relativized X and Y coordinates of the Prospect, Signal and Bald Hills stands on the Bray-Curtis indirect ordination. Index of similarity is the coefficient of community. Endpoint stands for the X-axis are 28 and 17, and for the Y-axis 21 and 49.

Stand	X Coordinate	Y Coordinate
1	97.1	19.4
2	85.9	16.0
3	91.0	31.6
4	95.7	31.9
5	49.5	22.5
6	65.3	13.9
7	85.0	16.6
8	55.7	25.7
9	54.3	18.7
10	85.7	40.2
11	57.7	11.3
12	46.3	51.9
13	68.0	48.1
14	61.5	39.8
15	41.0	43.4
16	33.8	23.0
17	100.0	20.2
18	62.6	5.0
19	46.2	22.6
20	37.7	20.8
21	50.2	0.0
22	47.0	14.4
23	42.8	20.7
24	74.4	17.6
25	29.2	11.1
26	40.9	17.8
27	29.1	9.2
28	0.0	20.4
29	47.7	14.9
30	38.2	24.3
31	54.7	52.2
32	42.2	36.9
33	34.3	43.6
34	48.3	38.9
35	49.2	38.7
36	57.5	52.6
37	53.4	46.7
38	45.5	73.1
39	40.1	37.3
40	40.0	42.7
41	28.2	48.4
42	34.3	38.3
43	25.0	37.2
44	35.6	75.1
45	40.9	73.7

Stand	X Coordinate	Y Coordinate
46	43.8	81.9
47	50.0	87.6
48	51.4	81.1
49	50.0	100.0
50	58.2	77.4
51	37.3	84.5
52	28.0	70.6
53	41.0	73.0
54	45.8	74.4
55	45.8	79.3
56	32.1	62.3
57	42.4	42.5
58	37.3	53.8
59	50.0	50.0
60	35.0	47.7
61	36.2	43.1
62	42.9	50.0
63	24.5	60.3
64	22.4	51.1
65	20.0	60.8
66	25.5	52.4
67	18.3	61.7
68	17.6	52.4
69	32.5	76.6
70	27.9	61.3
71	40.5	50.0
72	19.1	61.7
73	16.0	67.6